CMR College of Engineering & Technology
Kandlakoya (V), Medchal Road, Hyderabad - 501 401, Andhra Pradesh, INDIA
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COURSE DESCRIPTION

1. COURSE OBJECTIVES

To enable the students to

i. To study about the Distributed System Modeling, Clustering and Virtualization

ii. To gain knowledge about basic concepts of cloud computing.

iii. To learn Distinguish Infrastructure as a Service(IAAS) & Platform and Software as a Service(PAAS/SAAS).

iv. To study about Design & implementation of cloud computing applications.

v. To gain knowledge about important cloud computing driven commercial systems.

2. COURSE OUTCOMES

The student shall be able to

i. Explain Distributed System Modeling, Clustering and Virtualization

ii. Discuss basic concepts of cloud computing.

iii. Distinguish Infrastructure as a Service(IAAS) & Platform and Software as a Service(PAAS/SAAS).

iv. Design & implement cloud computing applications.

v. Explore some important cloud computing driven commercial systems.

PROGRAM OUTCOMES

CMR COLLEGE OF ENGINEERING & TECHNOLOGY

(UGC AUTONOMOUS)

KANDLAKOYA, MEDCHAL ROAD, HYDERABAD-501 401

ASSESSMENT OF PROGRAMME OUTCOMES & PROGRAMME SPECIFIC OUTCOMES

PROGRAMME **B.TECH (CSE)**

YEAR IV SEM VII Academic Year 2022-23 ***BATCH*** ***2019-2023***

Course Code A30542 Course Name Cloud Computing

ARTICULATION

S.No	COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
1	**CO1**	1	2	3		-	-	1	-	-	-	-		1	2
2	**CO2**	1	2	1	-	-	-	1	-	-	-	-	1	1	2
3	**CO3**	1	2	1	2	2	-	1	-	-	-	-	1	1	2
4	**CO4**	1	3	3	1	2	-	1	-	-	-	-	1	1	2
5	**CO5**	1	2	2	3	2	3	1	2	-	-	-	1	1	2
Average		**1.0**	**2.0**	**3.0**	**2.0**	**2.0**	**3.0**	**1.0**	**2.0**	**-**	**-**	**-**	**1.0**	**1.0**	**2.0**

FINAL ATTAINMENT (70% of External marks + 30% of Internal marks)					
Description	**CO1**	**C02**	**C03**	**CO4**	**CO5**
External Examinations Attainment	1.00	2.00	2.00	1.00	1.00
Internal Examinations Attainment	3.00	3.00	3.00	3.00	2.00
70% of External Examinations Attainment	0.70	1.40	1.40	0.70	0.70
30% of Internal Examinations	0.90	0.90	0.90	0.90	0.60
Final Attainment (70% of Ext + 30% of Int)	1.60	2.30	2.30	1.60	1.30
Equivalent attainment %	53.3%	76.7%	76.7%	53.3%	43.3%
Target attainment %	60.0%	60.0%	60.0%	60.0%	60.0%
Attainment Status (Y/N)	N	Y	Y	N	N

ATTAINMENT OF POs & PSOs THROUGH THE COURSE OUTCOMES

COs	**Attainment**	PO1	PO2	PO3	PO4	PO5	PO6	P07	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	**1.60**	1	2	3	0	-	-	1	-	-	-	-	0	1	2
CO2	**2.30**	1	2	1	-	-	-	1	-	-	-	-	1	1	2
CO3	**2.30**	1	2	1	2	2	-	1	-	-	-	-	1	1	2
CO4	**1.60**	1	3	3	1	2	-	1	-	-	-	-	1	1	2
CO5	**1.30**	1	2	2	3	2	3	1	2	-	-	-	1	1	2
Attainment		**1.82**	**1.80**	**1.68**	**1.68**	**1.73**	**1.30**	**1.82**	**1.30**	**-**	**-**	**-**	**1.88**	**1.82**	**1.82**

(Course Coordinator)

(Programme Coordinator)

(A30542) CLOUD COMPUTING
(PROFESSIONAL ELECTIVE-V)

B. Tech (CSE)

L	T	P	C
3	0	0	3

UNIT -I

Computing Paradigms: High-Performance Computing, Parallel Computing, Distributed Computing, Cluster Computing, Grid Computing, Cloud Computing, Bio computing, Mobile Computing, Quantum Computing, Optical Computing, Nano computing.

UNIT –II

Cloud Computing Fundamentals: Motivation for Cloud Computing, The Need for Cloud Computing, Defining Cloud Computing, Definition of Cloud computing, Cloud Computing Is a Service, Cloud Computing Is a Platform, Principles of Cloud computing, Five Essential Characteristics, Four Cloud Deployment Models.

UNIT –III

Cloud Computing Architecture and Management: Cloud architecture, Layer, Anatomy of the Cloud, Network Connectivity in Cloud Computing, Applications, on the Cloud, Managing the Cloud, Managing the Cloud Infrastructure Managing the Cloud application, Migrating Application to Cloud, Phases of Cloud Migration Approaches for Cloud Migration.

UNIT –IV

Cloud Service Models: Infrastructure as a Service, Characteristics of IaaS. Suitability of IaaS, Pros and Cons of IaaS, Summary of IaaS Providers, Platform as a Service, Characteristics of PaaS, Suitability of PaaS, Pros and Cons of PaaS, Summary of PaaS Providers, Software as a Service, Characteristics of SaaS, Suitability of SaaS, Pros and Cons of SaaS, Summary of SaaS Providers, Other Cloud Service Models.

UNIT –V

Cloud Service Providers: EMC, EMC IT, Captiva Cloud Toolkit, Google, Cloud Platform, Cloud Storage, Google Cloud Connect, Google Cloud Print, Google App Engine, Amazon Web Services, Amazon Elastic Compute Cloud, Amazon Simple Storage Service, Amazon Simple Queue, service, Microsoft, Windows

Azure, Microsoft Assessment and Planning Toolkit, SharePoint, IBM, Cloud Models, IBM Smart Cloud SAP Labs, SAP HANA Cloud Platform, Virtualization Services Provided by SAP, Sales force, Sales Cloud, Service Cloud: Knowledge as a Service, Rack space, VMware, Manjra soft, Aneka Platform.

Text Books:

1. Essentials of cloud Computing: K. Chandrasekhran, CRC press, 2014

Reference Books:

1. Cloud Computing: Principles and Paradigms by Rajkumar Buyya, James Broberg and Andrzej M. Goscinski, Wiley, 2011.
2. Distributed and Cloud Computing, Kai Hwang, Geoffery C. Fox, Jack J. Dongarra, Elsevier, 2012.
3. Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance, Tim Mather, Subra Kumaraswamy, Shahed Latif, O'Reilly, SPD, rp2011.

Course Outcomes

The student shall be able to

1. Explain Distributed System Modeling, Clustering and Virtualization
2. Discuss basic concepts of cloud computing.
3. Distinguish Infrastructure as a Service(IAAS) & Platform and Software as a Service(PAAS/SAAS).
4. Design & implement cloud computing applications.
5. Explore some important cloud computing driven commercial systems.

****END****

CMR COLLEGE OF ENGINEERING & TECHNOLOGY

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Kandlakoya, Medchal Road, Hyderabad – 501401.

Date: 05.06.2023

ACADEMIC CALENDAR

B.Tech IV Year - Academic Year 2023-2024

I Semester

S.No.	Description	Period	Duration
1	Commencement of Class Work	03.07.2023	--------
2	First Spell of Instructions	03.07.2023 to 26.08.2023	8Weeks
3	*First Mid Examinations*	*28.08.2023 to 02.09.2023*	1 Week
4	Submission of Mid-I Marks to Exam Branch	09.09.2023	
5	Parent-Teacher Meeting	16.09.2023	
6	Second Spell of Instructions (Including Dusara Vacation)*	04.09.2023 to 04.11.2023	9 Weeks
7	*Second Mid Examinations*	*06.11.2023 to 11.11.2023*	1 Week
8	Submission of Mid-II Marks to Exam Branch	18.11.2023	
9	Preparations and Practical Examinations	13.11.2023 to 18.11.2023	1 Week
10	*End Semester & Supplementary Examinations*	*20.11.2023 to 02.12.2023*	2 Weeks

II Semester

S.No	Description	Period	Duration
1	Commencement of Class Work	04.12.2023	--------
2	First Spell of Instructions	04.12.2023 to 27.01.2024	8 Weeks
3	*First Mid Examinations*	*29.01.2024 to 03.02.2024*	1 Week
4	Submission of Mid-I Marks to Exam Branch	10.02.2024	
5	Second Spell of Instructions	05.02.2024 to 30.03.2024	8 Weeks
6	*Second Mid Examinations*	*01.04.2024 to 06.04.2024*	1 Week
7	Submission of Mid-II Marks to Exam Branch	13.04.2024	
8	Preparations and Project Evaluation	08.04.2024 to 13.04.2024	1 Weeks
9	*End Semester & Supplementary Examinations*	*15.04.2024 to 27.04.2024*	2 Weeks

*Subjected to declaration by JNTUH/ Govt. of TS

05/6/2023

PRINCIPAL
CMR College of Engineering & Technology
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Kandlakoya, Medchal Road, Hyderabad.

Copy to: Secretary Garu/CEO for kind information please

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2. IQAC
3. All HODs
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5. Accounts Officer
6. Web Portal In charge
7. ERP In Charge
8. Library
9. Student Notice Boards.

CMR College of Engineering & Technology

Department of Computer Science & Engineering

SESSION PLANNER

Academic Year : 2023-2024 **Semester :** VII **Regulation :** R-18
Course Code : A30542 **Course** : Cloud Computing **Course Credits**: 3
Faculty Name: N.Nagaveni **Semester Start Date:** 03-07-2023 **Semester End Date:**

S.No	Subject Topic Name/ Sub Topic Name	Books	No. of Periods	Cumulative No. of Periods	Planned Week/Date	Completed Date	Delivery Method (White Board/ PPT/ Video links/ URLs /Animation/ Quiz/ Case study/ Model Show case/ 3DVisualization/Mentimeter/ Kahoot/Google classroom/ NPTEL Videos/Pod Cast/ Hands-on/Demos ...etc)
	UNIT-I						
1	Cloud Computing (CC) course importance and syllabus, CO	T1	1	1	03-07-2023		PPT
2	Introduction to Cloud Computing	T1	1	2			PPT, NPTEL
3	High performance computing, Parallel computing, Distributed computing	T1	2	4	To 10-07-2023		PPT
4	Cluster Computing, grid computing	T1	1	5	11-07-2023		PPT, NPTEL link
5	Cloud computing, Bio computing	T1	1	6			PPT, WB, Video links
6	Mobile computing, Quantum Computing	T1	1	7	To		PPT, WB, Hands-on
7	Optical computing and Nano computing	T1	1	8	18-07-2023		PPT, WB
	UNIT-II						
8	Motivation for cloud computing, The Need for cloud computing	T1	2	10	19-07-2023		PPT, WB
9	Defining Cloud Computing, Definition of	T1	1	11	To		PPT, WB

	cloud computing				24-07-2023		
10	Cloud computing Is a Service, Cloud computing Is a Platform	T1	1	12	25-07-2023		PPT, WB
11	Principles of Cloud Computing	T1	1	13	To		PPT, WB, Video links
12	Five Essential Characteristics	T1	1	14			PPT, WB
13	Four Cloud Deployment Models	T1	1	15	02-08-2023		PPT, WB
			UNIT-III				
14	Cloud Architecture, Layer	T1	2	17	03-08-2023		PPT, WB,
15	Anatomy of the cloud	T1	1	18			PPT, WB
16	Network Connectivity in Cloud computing, Applications on the Cloud	T1	2	20	To 14-08-2023		PPT, WB
17	Managing the Cloud, Managing the Cloud Infrastructure	T1	2	22	16-08-2023		PPT, WB
18	Managing the cloud application, Migrating Application to Cloud	T1	2	24	To		
19	Phases of Cloud Migration	T1	1	25	26-08-2023		PPT, WB
20	Approaches for cloud Migration	T1	2	27			PPT, WB
			UNIT-IV				
21	Infrastructure as a Service, Characteristics of IaaS, Suitability of IaaS	T1	1	28	04-09-2023		PPT, WB
22	Pros and Cons of IaaS, Summary of IaaS Providers. Platform as a Service	T1	2	30	To		PPT, WB
23	Characteristics of PaaS, Suitability of PaaS, Pros and Cons of PaaS, Summary ofPaaS providers, Software as a service	T1	2	32	12-09-2023		PPT, WB
24	Characteristics of SaaS, Suitability of SaaS, Pros and Cons of SaaS, Summary ofSaaS Providers, Other cloud of Service Models	T1	2	34	13-09-2023 To 20-09-2023		PPT, WB

				UNIT-V			
25	EMC, EMC IT, Captiva Cloud toolkit, Google, Cloud Platform, Cloud storage, Google cloud connect, Google Cloud Print, Google App Engine	T1	2	36	21-09-2023 To 30-09-2023		PPT, WB
26	Amazon web service, Amazon Elastic Compute Cloud, Amazon Simple Storage Service,Amazon Simple Queue service	T1	2	38			PPT, WB
27	Microsoft, Window, Azure, Microsoft Assessment and Planning Toolkit, Share Point,IBM	T1	2	40	03-10-2023 To 26-10-2023		PPT, WB, video links
28	Cloud Models, IBM Smart cloud SAP Labs, SAPHANA Cloud Platform, VirtualizationServices Provided by SAP	T1	2	42			PPT, WB
29	Sales Force, Sales Cloud, Service Cloud: Knowledge as a Service, Rackspace, VMware,Manjra Soft, Aneka Platform.	T1	2	44			PPT, WB
30	Revision		1	45			

Text Books:

1. Essentials of Cloud Computing: K. Chandrasekhran, CRC press, 2014

Reference Books:

1. Cloud Computing: Principles and Paradigms by Rajkumar Buyya, James Broberg and Andrzej M. Goscinski, Wiley, 2011.
2. Distributed and Cloud Computing, Kai Hwang, Geoffery C. Fox, Jack J. Dongarra, Elsevier, 2012.
3. Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance, Tim Mather, Subra Kumaraswamy, Shahed

Latif, O'Reilly,SPD, rp2011.

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The student shall be able to

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5. Explore some important cloud computing driven commercial systems.

Faculty Signature **HOD Signature**

CMR College of Engineering & Technology

Department of Computer Science & Engineering

CSE IV-1 PROFESSIONAL ELECTIVE-5

S.NO:	ROLL NO:	NAME OF THE STUDENT	SUBJECT OPTED
1	19H51A0563	Aleti Rohan Reddy	Cloud Computing
2	19H51A0575	K ARJUN	Cloud Computing
3	20H51A0514	Sandeep	Cloud Computing
4	20H51A0522	Tharunsai	Cloud Computing
5	20H51A0526	V Mahesh	Cloud Computing
6	20H51A0536	A.KARTHIK	Cloud Computing
7	20H51A0538	Rahul bharadwaj	Cloud Computing
8	20H51A0539	K.sushmitha	Cloud Computing
9	20H51A0555	Addala Shashi Kumar	Cloud Computing
10	20H51A0556	A S Srinath	Cloud Computing
11	20H51A0560	Cherukupally Ganesh	Cloud Computing
12	20H51A0561	ARUN TEJA	Cloud Computing
13	20H51A0562	D. Raja Goud	Cloud Computing
14	20H51A0575	YASHWANT .S	Cloud Computing
15	20H51A0585	B PRANAV SAI	Cloud Computing
16	20H51A0587	D.sri sanjana	Cloud Computing
17	20H51A0597	K.shaarvanie	Cloud Computing
18	20H51A0598	Manoj Kumar	Cloud Computing
19	20H51A0599	Marupatla Jithin	Cloud Computing
20	20H51A05A0	Mohammed Awais Khan	Cloud Computing
21	20H51A05A4	Savula Roshini	Cloud Computing
22	20H51A05A5	Prabhaneeth goud	Cloud Computing
23	20H51A05A6	Thotla Rakshika	Cloud Computing
24	20H51A05B4	Belde Pooja	Cloud Computing
25	20H51A05B7	BONALA NIKHIL	Cloud Computing
26	20H51A05B8	BUDDI TIRYAGISH PRAYAD	Cloud Computing
27	20H51A05B9	C.HARISHWAR REDDY	Cloud Computing
28	20H51A05C1	GADDAM HARDHIK	Cloud Computing
29	20H51A05C3	G Akshaya	Cloud Computing
30	20H51A05C5	Muralidhar Reddy	Cloud Computing
31	20H51A05D0	M srivardhan	Cloud Computing
32	20H51A05D2	Polkampeta Shreyansh Srikar rao	Cloud Computing
33	20H51A05D5	Yeleti Nithin	Cloud Computing
34	20H51A05D6	BANOTH GANESH	Cloud Computing
35	20H51A05E3	K Jeevitha	Cloud Computing
36	20H51A05E4	K.keerthana	Cloud Computing
37	20H51A05E8	MD.KHAJA TAZEEM HASHMEE	Cloud Computing
38	20H51A05G3	Atina Navya	Cloud Computing
39	20H51A05G4	Bommakanti varshith goud	Cloud Computing
40	20H51A05G8	G Harshavardhan reddy	Cloud Computing
41	20H51A05G9	G.Sainandhan	Cloud Computing
42	20H51A05H0	G. Supriya	Cloud Computing
43	20H51A05H2	Kallem Sruthi	Cloud Computing
44	20H51A05H4	Kellapu Yugender	Cloud Computing
45	20H51A05H6	M PAVAN KUMAR	Cloud Computing
46	20H51A05H8	M.Prithvi Raj Prabhu	Cloud Computing
47	20H51A05H9	Manganuri Pavan	Cloud Computing
48	20H51A05J0	Mulagalapati Venusri	Cloud Computing
49	20H51A05J1	Padakanti Shiva Charan	Cloud Computing
50	20H51A05J5	SAI ADITYA VARDHAN NAYANI	Cloud Computing

51	20H51A05J6	S.Neeraj kumar	Cloud Computing
52	20H51A05J8	U ANWESH GOUD	Cloud Computing
53	20H51A05J9	Kalvakuntla Dhathri guptha	Cloud Computing
54	20H51A05K9	Jarbula Harshini Naik	Cloud Computing
55	20H51A05L0	KANJARLA SUSHMARAJ	Cloud Computing
56	20H51A05M0	T Ajay	Cloud Computing
57	20H51A05M2	UPPARI HARSHITH	Cloud Computing
58	20H51A05M5	YEDAPALLY SANJANA	Cloud Computing
59	20H51A05M6	V VAMSHI	Cloud Computing
60	20H51A05M8	Avanaganti Ujwala	Cloud Computing
61	20H51A05N0	MANICHANDANA.B	Cloud Computing
62	20H51A05N1	B.AJAY KUMAR	Cloud Computing
63	20H51A05N2	Varun	Cloud Computing
64	20H51A05N5	Ch.varshini	Cloud Computing
65	20H51A05N7	G.vinayaswi	Cloud Computing
66	20H51A05N8	JARPULA SIVAKUMAR	Cloud Computing
67	20H51A05P0	K.Kavya Sree	Cloud Computing
68	20H51A05P7	Pucha Deepika	Cloud Computing
69	20H51A05Q1	IMTIYAZ AHMAD WANI	Cloud Computing
70	21H55A0501	B.Aravind	Cloud Computing
71	21H55A0502	BORUGALA PRABHANJALI	Cloud Computing
72	21H55A0503	Dasari Shivanjali	Cloud Computing
73	21H55A0504	Mahendra	Cloud Computing
74	21H55A0505	G.Prasanna Kumari	Cloud Computing
75	21H55A0506	Gollapally kavya	Cloud Computing
76	21H55A0507	G.Laxmi Vennela	Cloud Computing
77	21H55A0508	HOTKAR LAXMAN	Cloud Computing
78	21H55A0510	K.Manoj	Cloud Computing
79	21H55A0511	KETHAVATH SURESH	Cloud Computing
80	21H55A0512	Nithesh Madam	Cloud Computing
81	21H55A0513	Munipally Jyoshna	Cloud Computing
82	21H55A0514	Munkar Vaishnavi	Cloud Computing
83	21H55A0515	N. YESUMANI	Cloud Computing
84	21H55A0516	NAVAGARE AEYBA	Cloud Computing
85	21H55A0517	Panaganti Swetha	Cloud Computing
86	21H55A0518	Patil Saraswathi	Cloud Computing
87	21H55A0519	R Narasimha	Cloud Computing
88	21H55A0520	S.Sushma	Cloud Computing
89	21H55A0521	SHERLA BHAVANA	Cloud Computing
90	21H55A0522	SURAMPUDI KIRAN BABU	Cloud Computing
91	21H55A0523	S.Laxmi Narayana	Cloud Computing
92	21H55A0524	Vanaparthi Keerthana	Cloud Computing

HOD CSE

CMR College of Engineering & Technology

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Kandlakoya , Medchal Road - 501401

Department of Computer Science and Engineering

MID-I MARKS LIST

Class : IV B.Tech. I SEM CSE | **A.Y.2023-24**

SUBJECT : Cloud Computing(PE-V).....

S.No	Roll Number	Name of the Candidate	Assignment (5M)	MID Marks (25 M)	Total (30 M)
1	19H51A0563	Aleti Rohan Reddy	A	A	A
2	19H51A0575	K ARJUN	A	A	A
3	20H51A0514	Sandeep	4	12	16
4	20H51A0522	Tharunsai	5	17	22
5	20H51A0526	V Mahesh	4	10	14
6	20H51A0536	A.KARTHIK	5	17	22
7	20H51A0538	Rahul bharadwaj	A	16	16
8	20H51A0539	K.sushmitha	5	19	24
9	20H51A0555	Addala Shashi Kumar	A	10	10
10	20H51A0556	A S Srinath	5	19	24
11	20H51A0560	Cherukupally Ganesh	5	23	28
12	20H51A0561	ARUN TEJA	A	08	08
13	20H51A0562	D. Raja Goud	A	10	10
14	20H51A0575	YASHWANT .S	5	09	14
15	20H51A0585	B PRANAV SAI	A	A	A
16	20H51A0587	D.sri sanjana	5	16	21
17	20H51A0597	K.shaarvanie	5	18	23
18	20H51A0598	Manoj Kumar	5	15	20
19	20H51A0599	Marupatla Jithin	5	16	21
20	20H51A05A0	Mohammed Awais Khan	A	07	07
21	20H51A05A4	Savula Roshini	5	19	24
22	20H51A05A5	Prabhaneeth goud	5	A	05
23	20H51A05A6	Thotla Rakshika	5	20	25
24	20H51A05B4	Belde Pooja	5	19	24
25	20H51A05B7	BONALA NIKHIL	5	16	21
26	20H51A05B8	BUDDI TIRYAGISH PRAYAD	5	17	22
27	20H51A05B9	C.HARISHWAR REDDY	5	18	23
28	20H51A05C1	GADDAM HARDHIK	5	15	20
29	20H51A05C3	G Akshaya	5	19	24
30	20H51A05C5	Muralidhar Reddy	5	16	21
31	20H51A05D0	M srivardhan	5	16	21
32	20H51A05D2	Polkampeta Shreyansh Srikar rao	5	13	18
33	20H51A05D5	Yeleti Nithin	A	11	11
34	20H51A05D6	BANOTH GANESH	5	17	22
35	20H51A05E3	K Jeevitha	5	20	25

S.No	Roll Number	Name of the Candidate	Assignment (5M)	MID Marks (25 M)	Total (30 M)
71	21H55A0502	BORUGALA PRABHANJALI	5	19	24
72	21H55A0503	Dasari Shivanjali	5	19	24
73	21H55A0504	Mahendra	5	A	05
74	21H55A0505	G.Prasanna Kumari	5	22	27
75	21H55A0506	Gollapally kavya	5	21	26
76	21H55A0507	G.Laxmi Vennela	5	19	24
77	21H55A0508	HOTKAR LAXMAN	A	A	A
78	21H55A0510	K.Manoj	5	18	23
79	21H55A0511	KETHAVATH SURESH	5	20	25
80	21H55A0512	Nithesh Madam	5	18	23
81	21H55A0513	Munipally Jyoshna	5	20	25
82	21H55A0514	Munkar Vaishnavi	5	22	27
83	21H55A0515	N. YESUMANI	5	19	24
84	21H55A0516	NAVAGARE AEYBA	5	12	17
85	21H55A0517	Panaganti Swetha	5	18	23
86	21H55A0518	Patil Saraswathi	5	21	26
87	21H55A0519	R Narasimha	5	20	25
88	21H55A0520	S.Sushma	5	21	26
89	21H55A0521	SHERLA BHAVANA	5	21	26
90	21H55A0522	SURAMPUDI KIRAN BABU	5	15	20
91	21H55A0523	S.Laxmi Narayana	5	21	26
92	21H55A0524	Vanaparthi Keerthana	5	19	24

Name&Signature of the Faculty :	N. nagaveni
Department :	CSE
Mobile No :	9581829235

HOD/CSE

CMR College of Engineering & Technology

(UGC AUTONOMOUS)

Kandlakoya , Medchal Road - 501401

Department of Computer Science and Engineering

MID-I MARKS LIST

Class : IV B.Tech. I SEM CSE

SUBJECT : Cloud Computing(PE-V).....

A.Y.2023-24

S.No	Roll Number	Name of the Candidate	Assignment (5M)	MID Marks (25 M)	Total (30 M)
1	19H51A0563	Aleti Rohan Reddy	A	A	A
2	19H51A0575	K ARJUN	A	A	A
3	20H51A0514	Sandeep	5	10	15
4	20H51A0522	Tharunsai	5	17	22
5	20H51A0526	V Mahesh	5	13	18
6	20H51A0536	A.KARTHIK	5	20	25
7	20H51A0538	Rahul bharadwaj	5	17	22
8	20H51A0539	K.sushmitha	5	14	19
9	20H51A0555	Addala Shashi Kumar	5	12	17
10	20H51A0556	A S Srinath	5	20	25
11	20H51A0560	Cherukupally Ganesh	5	22	27
12	20H51A0561	ARUN TEJA	5	18	23
13	20H51A0562	D. Raja Goud	A	16	16
14	20H51A0575	YASHWANT .S	5	12	17
15	20H51A0585	B PRANAV SAI	A	A	A
16	20H51A0587	D.sri sanjana	5	16	21
17	20H51A0597	K.shaarvanie	5	23	28
18	20H51A0598	Manoj Kumar	5	16	21
19	20H51A0599	Marupatla Jithin	5	17	22
20	20H51A05A0	Mohammed Awais Khan	5	A	5
21	20H51A05A4	Savula Roshini	5	19	24
22	20H51A05A5	Prabhaneeth goud	5	18	23
23	20H51A05A6	Thotla Rakshika	5	20	25
24	20H51A05B4	Belde Pooja	5	19	24
25	20H51A05B7	BONALA NIKHIL	5	17	22
26	20H51A05B8	BUDDI TIRYAGISH PRAYAD	5	20	25
27	20H51A05B9	C.HARISHWAR REDDY	5	19	24
28	20H51A05C1	GADDAM HARDHIK	5	16	21
29	20H51A05C3	G Akshaya	5	18	23
30	20H51A05C5	Muralidhar Reddy	5	15	20
31	20H51A05D0	M srivardhan	5	19	24
32	20H51A05D2	Polkampeta Shreyansh Srikar rao	5	16	21
33	20H51A05D5	Yeleti Nithin	5	12	17
34	20H51A05D6	BANOTH GANESH	5	21	26
35	20H51A05E3	K Jeevitha	5	16	21

S.No	Roll Number	Name of the Candidate	Assignment (5M)	MID Marks (25 M)	Total (30 M)
71	21H55A0502	BORUGALA PRABHANJALI	5	17	22
72	21H55A0503	Dasari Shivanjali	5	22	27
73	21H55A0504	Mahendra	5	18	23
74	21H55A0505	G.Prasanna Kumari	5	24	29
75	21H55A0506	Gollapally kavya	5	21	26
76	21H55A0507	G.Laxmi Vennela	5	22	27
77	21H55A0508	HOTKAR LAXMAN	A	A	A
78	21H55A0510	K.Manoj	5	20	25
79	21H55A0511	KETHAVATH SURESH	5	20	25
80	21H55A0512	Nithesh Madam	5	21	26
81	21H55A0513	Munipally Jyoshna	5	16	21
82	21H55A0514	Munkar Vaishnavi	5	24	29
83	21H55A0515	N. YESUMANI	5	22	27
84	21H55A0516	NAVAGARE AEYBA	5	13	18
85	21H55A0517	Panaganti Swetha	5	20	25
86	21H55A0518	Patil Saraswathi	5	23	28
87	21H55A0519	R Narasimha	5	22	27
88	21H55A0520	S.Sushma	5	22	27
89	21H55A0521	SHERLA BHAVANA	5	23	28
90	21H55A0522	SURAMPUDI KIRAN BABU	5	17	22
91	21H55A0523	S.Laxmi Narayana	5	22	27
92	21H55A0524	Vanaparthi Keerthana	5	18	23

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HOD/CSE

CMR College of Engineering & Technology

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B.TECH-IV/IV I SEM Regular Results Analysis Held in November 2023: Final Result Curriculum: R18 Rev2

Branch **ELECTRONICS & COMMUNICATION ENGINEERING**

Subject	Reg	App	Passed	Failed	Reg Pass %	Apprd. Pass %
NTREPRENEURSHIP :30164)	7	7	6	1	85.71	85.71
R POLLUTION & CONTROL 130163)	74	74	72	2	97.30	97.30
NVIRONMENTAL PROTECTION AND MANAGEMENT 130166)	39	39	39	0	100.00	100.00
/ASTE TO ENERGY 130378)	6	6	6	0	100.00	100.00
LOUD COMPUTING A30542)	17	17	15	2	88.24	88.24
NTRODUCTION TO DATA SCIENCE A30559)	10	10	9	1	90.00	90.00
A OF INSURANCE AND TAXATION C....5)	15	15	13	2	86.67	86.67
MARKETING MANAGEMNET C30167)	41	41	40	1	97.56	97.56
MAJOR PROJECT PHASE-I A30428)	249	249	225	24	90.36	90.36
MINI PROJECT-II A30426)	116	116	116	0	100.00	100.00
SUMMER INTERNSHIP-II (A30427)	133	133	133	0	100.00	100.00
ALL SUBJECTS	249	248	212	36	85.14	85.48

Branch **COMPUTER SCIENCE & ENGINEERING**

Subject	Reg	App	Passed	Failed	Reg Pass %	Apprd. Pass %
BUSINESS MANAGEMENT & FINANCIAL ANALYSIS (A30013)	260	258	247	11	95.00	95.74
DESIGN PATTERNS (A....34)	226	225	214	11	94.69	95.11
MACHINE LEARNING (A30535)	34	34	31	3	91.18	91.18
DATA ANALYTICS WITH R (A30537)	59	59	55	4	93.22	93.22
DEEP LEARNING (A30538)	66	66	61	5	92.42	92.42
ETHICAL HACKING (A30539)	135	134	124	10	91.85	92.54
BIG DATA ANALYTICS (A30540)	172	171	167	4	97.09	97.66
CLOUD COMPUTING (A30542)	88	86	76	10	86.36	88.37
KNOWLEDGE MANAGEMENT (C30162)	50	49	45	4	90.00	91.84
PYTHON PROGRAMMING (A30531)	48	48	45	3	93.75	93.75

Controller of Examinations

Principal

Set-1

Hall Ticket No. | | | | | | | | | | |

Question Paper Code:A30542

CMR COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS)

B.Tech VII Semester Mid-I Examinations August -2023

(Regulation: CMRCET-R18)

Subject Name: Cloud Computing **Time: 10.00 AM to 11.40 AM**

Date:02 -09-2023 FN **Branch: CSE** **Max Marks: 25**

PART A

Answer all FIVE questions (Compulsory)

Each question carries TWO marks. **5x2=10M**

Question Number	Question Format	CO	B.T Level
1	Define what is Grid Computing?	I	1
2	Define Cloud Computing?	I	1
3	summarize the Five essential characteristics of cloud?	II	2
4	Describe cloud computing is a platform?	II	1
5	What is elasticity?	III	1

PART B

Answer ALL questions.

Each question carries FIVE Marks. **3x5=15M**

Question Number	Question Format	CO	B.T Level
6. A.	Summarize the necessary to understand the various computer paradigms?	I	2
	OR		
6. B.	Explain in detail about Mobile computing and Quantum computing?	I	1
7. A.	Explain in detail about Service offering models?	II	1
	OR		
7. B.	Discuss the Deployment models of the cloud?	II	2
8. A.	Describe cloud Architecture with suitable diagram?	III	1
	OR		
8. B.	Describe Network Connectivity in cloud computing?	III	1

SET-2

Hall Ticket No. | | | | | | | | | | |

Question Paper Code:A30542

CMR COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS)

B.Tech VII Semester Mid-I Examinations August -2023

(Regulation: CMRCET-R18)

Subject Name:Cloud Computing **Time: 10.00 AM to 11.40 AM**

Date:02 -09-2023 **Branch: CSE** **Max Marks: 25**

PART A

Answer all FIVE questions (Compulsory)

Each question carries TWO marks. **5x2=10M**

Question Number	Question Format	CO	B.T Level
1	Describe cluster computing?	I	1
2	Summarize how the nano computing shape future devices?	I	2
3	Discuss about the need of cloud computing?	II	2
4	Illustrate cloud computing is a service?	II	4
5	What is server consolidation?	III	1

PART B

Answer ALL questions.

Each question carries FIVE Marks. **3x5=15M**

Question Number	Question Format	CO	B.T Level
6A	Explain in detail about grid computing and it's pros and cons?	I	1
	OR		
6B	Define cloud computing and write short note on mobile computingand bio computing?	I	1
7A	Discribe Five essential characteristics of cloud computing?	II	1
	OR		
7B	Discuss what are the applications on the cloud?	III	1
8A	Describe cloud architecture with suitable diagram?	III	1
	OR		
8B	Explain how is cloud anatomy different from cloud architecture?	III	1

****END****

SET-1

Hall Ticket No. | | | | | | | | Question Paper Code:A30542

CMR COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS)

B.Tech VII Semester Mid-II Examinations November -2023

(Regulation: CMRCET-R18)

Subject Name: Cloud Computing **Time:**

Date: -11-2023 **Branch: CSE** **Max Marks: 25**

PART A

Answer all FIVE questions (Compulsory)
Each question carries TWO marks. **5x2=10M**

Question Number	Question Format	CO	B.T Level
1	Why are SLAs important in cloud computing?	III	1
2	Define infrastructure as a service(IaaS)?	IV	1
3	Write short notes on characteristics of PaaS and SaaS?	IV	1
4	Define cloud service providers? which are the major cloud service providers?	V	1
5	Describe the support services offered by amazon web services?	V	1

PART B

Answer ALL questions.
Each question carries FIVE Marks. **3x5=15M**

Question Number	Question Format	CO	B.T Level
6. A.	Describe several approaches of cloud migration and list the phases of cloud migration ?	III	1
	OR		
6. B.	Explain the drawbacks of a web application?	III	1
7. A.	Write short notes on pros and cons of IaaS and SaaS?	IV	1
	OR		
7. B.	Explain in detail about the overview of IaaS and SaaS with suitable diagram?	IV	1
8. A.	Discuss about the services offered by IBM Smart cloud?	V	2
	OR		
8. B.	Describe the overview of Aneka platform with suitable diagram?	V	1

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Hall Ticket No.

SET-2

Question Paper Code: A30542

CMR COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS)

B.Tech VII Semester Mid-II Examinations November -2023

(Regulation: CMRCET-R18)

Subject Name: Cloud Computing **Time:**

Date: -11-2023 **Branch: CSE** **Max Marks: 25**

PART A

Answer all FIVE questions (Compulsory)

Each question carries TWO marks. **5x2=10M**

Question Number	Question Format	CO	B.T Level
1	Define public cloud access networking?	III	1
2	Define platform as a service(PaaS)?	IV	1
3	Discuss about the suitability of software as a service(SasS)?	IV	2
4	Explain SAPHANA Cloud in brief?	V	1
5	What do you mean by Knowledge as a service? Which company provides this service?	V	1

PART B

Answer ALL questions.

Each question carries FIVE Marks. **3x5=15M**

Question Number	Question Format	CO	B.T Level
6A	Discuss about the two different cloud management classifications?	III	2
	OR		
6B	Summarize end user and service provider responsibilities of cloud service models with a suitable diagram?	IV	2
7A	Discuss about summary of popular IaaS providers?	IV	2
	OR		
7B	Discuss about the Deployment and delivery of cloud service models with a neat diagram?	IV	2
8A	What is Vcloud? Explain in brief?	V	1
	OR		
8B	Describe about the Google app engine with suitable architecture?	V	1

****END****

MID -I SOLUTIONS

1) Define what is Grid Computing?

The computing resources in most of the organizations are underutilized but are necessary for certain operations. The idea of grid computing is to make use of such nonutilized computing power by the needy organizations, and thereby the return on investment (ROI) on computing investments can be increased.

Thus, grid computing is a network of computing or processor machines managed with a kind of software such as middleware, in order to access and use the resources remotely.

The managing activity of grid resources throughthe middleware is called **grid services.** Grid services provide access control, security, access to data including digital libraries and databases, and access to large-scale interactive and long-term storage facilities.

2) Define Cloud Computing?

In the simplest terms, cloud computing means storing and accessing data and programs over the Internet from a remote location or computer instead of our computer's hard drive.

This so called remote location has several properties such as scalability, elasticity etc., which is significantly different from a simple remote machine. The cloud is just a metaphor for the Internet.

When we store data on or run a program from the local computer's hard drive, that is called local storage and computing. For it to be considered *cloud computing*, we need to access our data or programs over the Internet. The end result is the same; however, with an online connection, cloud computing can be done anywhere, anytime, and by any device.

3) summarize the Five essential characteristics of cloud?

2.1.1 Five Essential Characteristics

Cloud computing has five essential characteristics, which are shown inFigure 2.2. Readers can note the word *essential*, which means that if any of these characteristics is missing, then it is not cloud computing:

1. **On-demand self-service:** A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction witheach service's provider.

2. **Broad network access**: Capabilities are available over the network andaccessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and personal digital assistants [PDAs]).

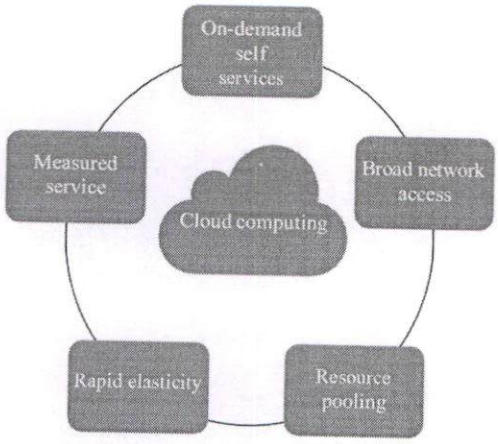

FIGURE 2.2
The essential characteristics of cloud computing.

3. **Elastic resource pooling**: The provider's computing resources are pooled to serve multiple consumers using a multitenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but maybe able to specify the location at a higher level of abstraction (e.g., country, state, or data center). Examples of resources include storage, processing, memory, and network bandwidth.
4. **Rapid elasticity**: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.
5. **Measured service**: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

4) Describe cloud computing is a platform?

The World Wide Web (WWW) can be considered as the operating system for all our Internet-based applications. However, one has to understand that we will always need a local operating system in our computer to access web-based applications.

The basic meaning of the term *platform* is that it is the support on which applications run or give results to the users. For example, Microsoft Windows is a platform. But, a platform does not have to be an operating system. Java is a platform even though it is not an operating system.

Through cloud computing, the web is becoming a platform. With trends (applications) such as Office 2.0, more and more applications that were originally available on desktop computers are now being converted into web–cloud applications. Word processors like Buzzword and office suites like Google Docs are now available in the cloud as their desktop counter-

parts. All these kinds of trends in providing applications via the cloud are turning cloud computing into a platform or to act as a platform.

5) What is elasticity?

Elasticity is also a unique property that enables the cloud to serve better. According to Herbst et al. elasticity can be definedas the degree to which a system is able to adapt to workload changesby provisioning and deprovisioning resources in an autonomic man-ner such that at each point in time, the available resources match thecurrent demand as closely as possible. Elasticity allows the cloud providers to efficiently handle the number of users, from one to

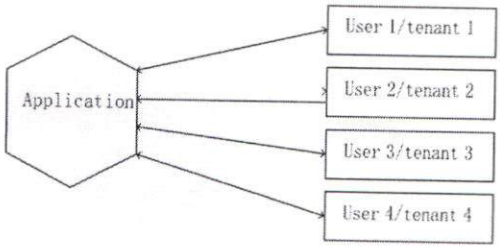

FIGURE 3.5
Multitenancy.

several hundreds of users at a time. In addition to this, it supports the rapid fluctuation of loads, that is, the increase or decrease in the number of users and their usage can rapidly change.

6 .A Summarize the necessary to understand the various computer paradigms?

Understanding various computer paradigms is essential in the context of cloud computing for several reasons:

- **Scalability**: Different paradigms offer different approaches to scaling applications. Understanding paradigms like distributed computing, parallel computing, and grid computing helps in designing and deploying applications that can scale effectively in a cloud environment.

- **Resource Management:** Cloud computing relies on efficient resource management to allocate computing resources dynamically. Knowledge of paradigms like virtualization, containerization, and serverless computing helps in optimizing resource utilization and cost-effectiveness in the cloud.

- **Fault Tolerance and Reliability:** Cloud computing environments need to be resilient to failures. Understanding paradigms like fault tolerance, redundancy, and resilience engineering aids in designing systems that can withstand failures and maintain high availability.

- **Data Handling:** Handling large volumes of data is a fundamental aspect of cloud computing. Various paradigms like distributed databases, data

streaming, and big data processing provide different approaches to managing and analyzing data efficiently in the cloud.

- **Programming Models:** Different programming paradigms, such as imperative, declarative, functional, and event-driven programming, offer different ways of structuring and solving problems. Understanding these paradigms helps in choosing appropriate programming models and frameworks for developing cloud-based applications.

- **Security and Privacy:** Security is a major concern in cloud computing. Understanding paradigms related to encryption, authentication, access control, and compliance helps in implementing robust security measures to protect data and applications in the cloud.

- **Interoperability and Integration**: Cloud computing often involves integrating diverse systems and services. Understanding various paradigms facilitates interoperability between different systems and enables seamless integration of cloud-based services with existing infrastructure.

understanding various computer paradigms is crucial for effectively leveraging cloud computing technologies, optimizing performance, ensuring reliability and security, and designing scalable and resilient cloud-based applications.

6 .B Explain in detail about mobile computing and quantum computing?

Mobile Computing:

1) In mobile computing, the processing (or computing) elements are small (i.e., handheld devices) and the communication between various resources is taking place using wireless media.
2) Mobile communication for voice applications (e.g., cellular phone) is widely established throughout the world and witnesses a very rapid growth in all its dimensions including the increase in the number of subscribers of various cellular networks.
3) An extension of this technology is the ability to send and receive data across various cellular networks using small devices such as smartphones.
4) There can be numerous applications based on this technology; for example, video call or conferencing is one of the important applications that people prefer to use in place of existing voice (only) communications on mobile phones.
5) Mobile computing–based applications are becoming very important and rapidly evolving with various technological advancements as it allows users to transmit data from remote locations to other remote or fixed locations.

Quantum Computing:

1) Manufacturers of computing systems say that there is a limit for cramming more and more transistors into smaller and smaller spaces of inte-

grated circuits (ICs) and thereby doubling the processing power about every 18 months.

2) This problem will have to be overcome by a new *quantum computing*–based solution, wherein the dependence is on quantum infor- mation, the rules that govern the subatomic world.

3) Quantum computers are millions of times faster than even our most powerful supercomputers today.

4) Since quantum computing works differently on the most fundamen- tal level than the current technology, and although there are working pro- totypes, these systems have not so far proved to be alternatives to today's silicon-based machines.

5) Quantum Computing is a subfield of Quantum Information Science. It describes the best way of dealing with a complicated computation. Quantum-mechanics is based on the phenomena of **superposition** and **entanglement**, which are used to perform the quantum computations.

6) A Quantum deals with the smallest particles found in nature. i.e., electrons and photons. These three particles are known as **Quantum particles**. In this, superposition defines the ability of a quantum system to be present in multiple states (one or more) at the same time.

7) **For example**, a time machine in which a person can be present at one or more places at the same time, or we can say something that is present up, down, here and there at the same time. It is known as **superposition.**

8) defines a very strong correlation between the quantum particles. These particles are so strongly linked that even if we place one particle at one end of the universe and one at the other end, both of them dance instantaneously.

9) A Quantum Computer is a device that is used for performing quantum calculations, which are highly complex in nature. It stores data in the form of **Qubits**. Qubits are also known as **Quantum Bits**. A Quantum Computer can simulate those problems or operations that a classical computer (that we currently use) cannot do. Even a quantum computer is capable of solving computational problems faster than a normal computer.

10) **For example**, it is easy to get the product of (500 * 187625) through a classical computer, but it is easy and quick to get the same result through a quantum computer. A classical computer will take approximately 5 seconds to get the result, whereas a quantum computer will take 0.005 seconds to get the result.

11) Currently, researchers are working with Quantum computers in the field of cybersecurity to break codes and encrypt electronic communications to explore better cybersecurity and protected data.

7.A Explain in detail about Service offering models?

The three kinds of services with which the cloud-based computing resources are available to end customers are as follows:

Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). It is also known as the service–platform–infrastructure

(SPI) model of the cloud and is shown in Figure 2.3. SaaS is a software distribution model in which applica-tions (software, which is one of the most important computing resources) arehosted by a vendor or service provider and made available to customers overa network, typically the Internet.

PaaS is a paradigm for delivering operatingsystems and associated services (e.g., computer aided software engineering [CASE] tools, integrated development environments [IDEs] for developing software solutions) over the Internet without downloads or installation. IaaS involves outsourcing the equipment used to support operations, including storage, hardware, servers, and networking components.

1. **Cloud SaaS**: The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure, includ- ing network, servers, operating systems, storage, and even individ- ual application capabilities, with the possible exception of limited user-specific application configuration settings. The applications are accessible from various client devices through either a thin client

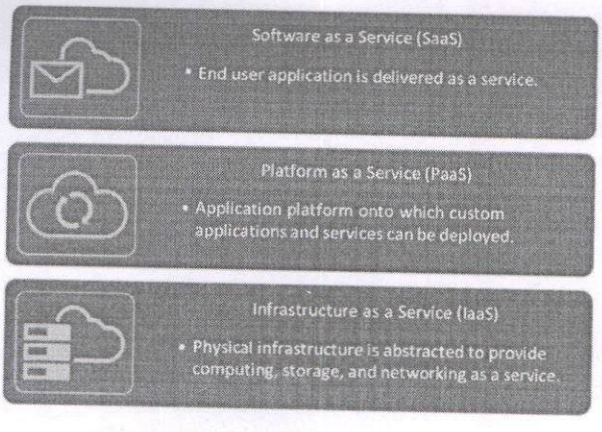

FIGURE 2.3
SPI—service offering model of the cloud.

interface, such as a web browser (e.g., web-based e-mail), or a program interface. The consumer does not manage or control the underlying cloud infrastructure. Typical applications offered as a service include customer relationship management (CRM), business intelligence analytics, and online accounting software.

2. **Cloud PaaS**: The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applica- tions created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage orcontrol the underlying cloud infrastructure but has control over thedeployed applications and possibly configuration settings for the application-hosting environment. In other words, it is a packaged and ready-to-run

development or operating framework. The PaaS vendor provides the networks, servers, and storage and manages the levels of scalability and maintenance. The client typically pays for services used. Examples of PaaS providers include Google App Engine and Microsoft Azure Services.

3. **Cloud IaaS**: The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources on a pay-per-use basis where he or she is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over the operating systems, storage, and deployed applications and possibly limited control of select networking components (e.g., host firewalls). The service provider owns the equipment and is responsible for housing, cooling operation, and maintenance. Amazon Web Services (AWS) isa popular example of a large IaaS provider.

The major difference between PaaS and IaaS is the amount of control that users have. In essence, PaaS allows vendors to manage everything, while IaaS requires more management from the customer side. Generally speak- ing, organizations that already have a software package or application for a specific purpose and want to install and run it in the cloud should opt to use IaaS instead of PaaS.

7.B Discuss the Deployment models of the cloud?

Deployment models describe the ways with which the cloud services can be deployed or made available to its customers, depending on the organizational structure and the provisioning location.

One can understand it in this man- ner too: cloud (Internet)-based computing resources—that is, the locations where data and services are acquired and provisioned to its customers— can take various forms.

Four deployment models are usually distinguished, namely, public, private, community, and hybrid cloud service usage:

1. **Private cloud**: The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.
2. **Public cloud**: The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
3. **Community cloud**: The cloud infrastructure is shared by several organizations and supports a specific community that has shared con- cerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on premise or off premise.
4. **Hybrid cloud**: The cloud infrastructure is a composition of two or

more distinct cloud infrastructures (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application porta- bility (e.g., cloud bursting for load balancing between clouds).

8.A Describe cloud Architecture with suitable diagram?

Any technological model consists of an architecture based on which the model functions, which is a hierarchical view of describing the technology. The cloud also has an architecture that describes its working mechanism. It includes the dependencies on which it works and the components that work over it. The cloud is a recent technology that is completely depen-dent on the Internet for its functioning. Figure 3.1 depicts the architecture. The cloud architecture can be divided into four layers based on the access ofthe cloud by the user. They are as follows.

1) Layer 1 (User/Client Layer)

This layer is the lowest layer in the cloud architecture. All the users or client belong to this layer. This is the place where the client/user initiates the

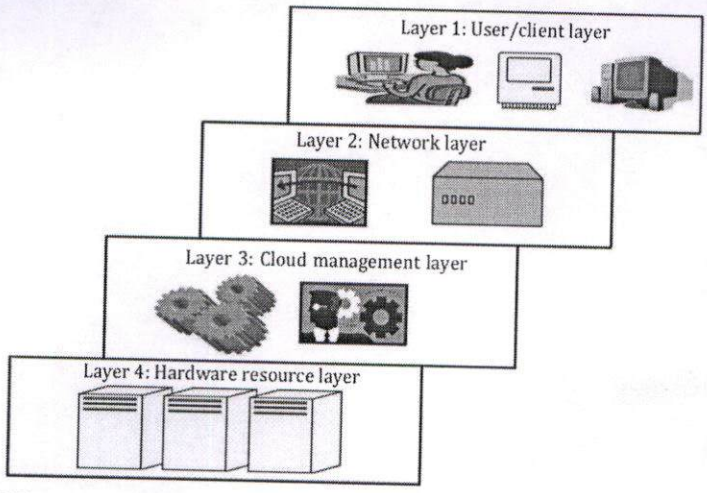

FIGURE 3.1
Cloud architecture

connection to the cloud. The client can be any device such as a thin client, thick client, or mobile or any handheld device that would support basic functionalities to access a web application. The thin client here refers to a device that is completely dependent on some other system for its complete functionality. In simple terms, they have very low processing capability. Similarly, thick clients are general computers that have adequate processing capability. They have sufficient capability for independent work. Usually, a cloud application can be accessed in the same way as a web application. But internally,

the properties of cloud applications are significantly different. Thus, this layer consists of client devices.

2) Layer 2 (Network Layer)

This layer allows the users to connect to the cloud. The whole cloud infrastructure is dependent on this connection where the services are offered to the customers. This is primarily the Internet in the case of a public cloud. The public cloud usually exists in a specific location and the user would not know the location as it is abstract. And, the public cloud can be accessed all over the world. In the case of a private cloud, the connectivity may be pro- vided by a local area network (LAN). Even in this case, the cloud completely depends on the network that is used. Usually, when accessing the public or private cloud, the users require minimum bandwidth, which is sometimes defined by the cloud providers. This layer does not come under the purview of service-level agreements (SLAs), that is, SLAs do not take into account the Internet connection between the user and cloud for quality of service (QoS).

3) Layer 3 (Cloud Management Layer)

This layer consists of softwares that are used in managing the cloud. The softwares can be a cloud operating system (OS), a software that acts as an interface between the data center (actual resources) and the user, or a management software that allows managing resources. These softwares usually allow resource management (scheduling, provisioning, etc.), optimization (server consolidation, storage workload consolidation), and internal cloud governance. This layer comes under the purview of SLAs, that is, the operations taking place in this layer would affect the SLAs that are being decided upon between the users and the service providers. Any delay in processing or any discrepancy in service provisioning may lead to an SLA violation. As per rules, any SLA violation would result in a penalty to be given by the service provider. These SLAs are for both private and public clouds Popular service providers are Amazon Web Services (AWS) and Microsoft Azure for public cloud. Similarly, OpenStack and Eucalyptus allow private cloud creation, deployment, and management.

4) Layer 4 (Hardware Resource Layer)

Layer 4 consists of provisions for actual hardware resources. Usually, in the case of a public cloud, a data center is used in the back end. Similarly, in a private cloud, it can be a data center, which is a huge collection of hardware resources interconnected to each other that is present in a specific location or a high configuration system. This layer comes under the purview of SLAs. This is the most important layer that governs the SLAs. This layer affects the SLAs most in the case of data centers. Whenever a user accesses the cloud, it should be available to the users as quickly as possible and should be within the time that is defined by the SLAs. As mentioned, if there is any discrep- ancy in provisioning the resources or application, the service provider has to pay the penalty. Hence, the data center consists of a high-speed network connection and a highly efficient algorithm to transfer the data from the datacenter to the manager. There can be a number of data centers for a cloud, and similarly, a number of clouds can share a data center.

Thus, this is the architecture of a cloud. The layering is strict, and for any cloud application, this is followed. There can be a little loose isolation between layer 3 and layer 4 depending on the way the cloud is deployed.

8.B Describe Network Connectivity in cloud computing?

Cloud computing is a technique of resource sharing where servers, storage, and other computing infrastructure in multiple locations are connected by networks. In the cloud, when an application is submitted for its execution, needy and suitable resources are allocated from this collection of resources; as these resources are connected via the Internet, the users get their required results. For many cloud computing applications, network performance will be the key issue to cloud computing performance. Since cloud computing has various deployment options, we now consider the important aspects related to the cloud deployment models and their accessibility from the viewpoint of network connectivity.

1) Public Cloud Access Networking

- In this option, the connectivity is often through the Internet, though some cloud providers may be able to support virtual private networks (VPNs) for customers.
- Accessing public cloud services will always create issues related to security, which in turn is related to performance.
- One of the pos- sible approaches toward the support of security is to promote connectivity through encrypted tunnels, so that the information may be sent via secure pipes on the Internet.
- This procedure will be an overhead in the connectiv- ity, and using it will certainly increase delay and may impact performance.
- If we want to reduce the delay without compromising security, then we have to select a suitable routing method such as the one reducing the delay by minimizing transit *hops* in the end-to-end connectivity between the cloud provider and cloud consumer.
- Since the end-to-end connectivity support is via the Internet, which is a
- Complex federation of the interconnected providers (known as Internet
- service providers [ISPs]),one has to look at the options of selecting the path.

2) Private Cloud Access Networking

- In the private cloud deployment model, since the cloud is part of an organi-zational network, the technology and approaches are local to the in-house network structure.
- This may include an Internet VPN or VPN service from a network operator.
- If the application access was properly done with an orga-nizational network—connectivity in a *precloud* configuration—transition to private cloud computing will not affect the access performance.

3) Intracloud Networking for Public Cloud Services

- Another network connectivity consideration in cloud computing is intra-cloud networking for public cloud services.

- Here, the resources of the cloud provider and thus the cloud service to the customer are based on the resources that are geographically apart from each other but still connected via the Internet.
- Public cloud computing networks are internal to the ser- vice provider and thus not visible to the user/customer; however, the secu- rity aspects of connectivity and the access mechanisms of the resources are important.
- Another issue to look for is the QoS in the connected resources worldwide. Most of the performance issues and violations from these are addressed in the SLAs commercially.

4) Private Intracloud Networking

- The most complicated issue for networking and connectivity in cloud com- puting is private intracloud networking.
- What makes this particular issue so complex is that it depends on how much intracloud connectivity is associ- ated with the applications being executed in this environment. Private intra-cloud networking is usually supported over connectivity between the major data center sites owned by the company. At a minimum, all cloud computing implementations will rely on intracloud networking to link users with the resource to which their application was assigned.
- Once the resource link- age is made, the extent to which intracloud networking is used depends on whether the application is componentized based on service-oriented architec- ture (SOA) or not, among multiple systems.
- If the principle of SOA is fol- lowed, then traffic may move between components of the application, as well as between the application and the user. The performance of those connec- tions will then impact cloud computing performance overall.
- Here too, the impact of cloud computing performance is the differences that exist between the current application and the network relationships with the application.

There are reasons to consider the networks and connectivity in cloud computing with newer approaches as globalization and changing network requirements, especially those related to increased Internet usage, are demanding more flexibility in the network architectures of today's enter- prises. How are these related to us? The answers are discussed later.

5) New Facets in Private Networks

- Conventional private networks have been architected for on-premise applica-tions and maximum Internet security.
- Typically, applications such as e-mail, file sharing, and *enterprise resource planning* (ERP) systems are delivered to on-premise-based servers at each corporate data center. Increasingly today, software vendors are offering Software as a Service (SaaS) as an alternative for their software support to the corporate offices, which brings more chal- lenges in the access and usage mechanisms of software from data center servers and in the connectivity of network architectures.
- The traditional net-work architecture for these global enterprises was not designed to optimize performance for cloud applications, now that many

applications including

- mission-critical applications are transitioning (moving) from on-premise based to cloud based, wherein the network availability becomes as mission critical as electricity: the business cannot function if it cannot access applica-tions such as ERP and e-mail.

6) Path for Internet Traffic

- The traditional Internet traffic through a limited set of Internet gateways poses performance and availability issues for end users who are using cloud-based applications.
- It can be improved if a more widely distributed Internet gateway infrastructure and connectivity are being supported for accessing applications, as they will provide lower-latency access to their cloud applications.
- As the volume of traffic to cloud applications grows, thepercentage of the legacy network's capacity in terms of traffic to regional gateways increases.
- Applications such as video conferencing would hog more bandwidth while mission-critical applications such as ERP will con- sume less bandwidth, and hence, one has to plan a correct connectivity and path between providers and consumers.

MID-2 SOLUTIONS

1) Define public cloud access networking?

In this option, the connectivity is often through the Internet, though some cloud providers may be able to support virtual private networks (VPNs) for customers.

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Since the end-to-end connectivity support is via the Internet, which is a complex federation of interconnected providers (known as Internet service providers [ISPs]), one has to look at the options ofselecting the path.

2) Define infrastructure as a service(IaaS)?

1. **IaaS**: The ability given to the infrastructure architects to deploy or run any software on the computing resources provided by the ser- vice provider. Here, the underlying infrastructures such as compute, network, and storage are managed by the service provider. Thus, the infrastructure architects are exempted from maintaining the data center or underlying infrastructure. The end users are responsible for managing applications that are running on top of the service

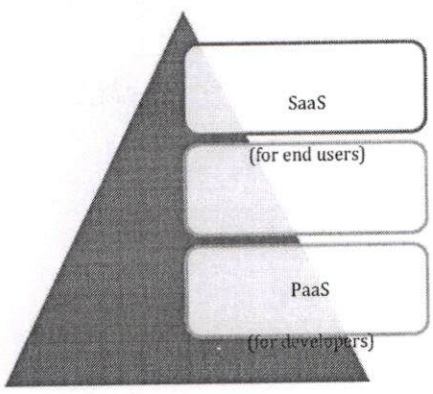


FIGURE 5.1
Basic cloud service models.

3) Write short notes on characteristics of PaaS and SaaS?

Characteristics of PaaS:

1. **All in one**: Most of the PaaS providers offer services to develop, test, deploy, host, and maintain applications in the same IDE.
2. **Web access to the development platform**: A typical development plat- form uses any IDEs for developing applications. Typically, the IDE will be installed in the developer's machines. But, PaaS provides web access to the development platform.
3. **Offline access**: A developer may not be able to connect to the Internetfor a whole day to access the PaaS services. When there is no Internet connectivity, the developers should be allowed to work offline.
4. **Built-in scalability**: Scalability is an important requirement for the new-generation web or SaaS applications. It is very difficult to enable thedynamic scalability for any application developed using traditional development platforms. But, PaaS services provide built-in scalability toan application that is developed using any particular PaaS.
5. **Collaborative platform**: Nowadays, the development team consists of developers who are working from different places. There is a need for a common platform where the developers can collaboratively work together on the same project.
6. **Diverse client tools**: To make the development easier, PaaS providersprovide a wide variety of client tools to help the developer. The client tools include CLI, web CLI, web UI, REST API, and IDE.

Characteristics of SaaS:

1. **One to many**: SaaS services are delivered as a one-to-many model where a single instance of the application can be shared by multipletenants or customers.
2. **Web access:** SaaS services provide web access to the software. It allowsthe end user to access the application from any location if the deviceis connected to the Internet.
3. **Centralized management**: Since SaaS services are hosted and man- aged from the central location, management of the SaaS applica- tion becomes easier.
4. **Multidevice support:** SaaS services can be accessed from any end userdevices such as desktops, laptops, tablets, smartphones, and thin clients.
5. **Better scalability:** Since most of the SaaS services leverage PaaS and IaaS for its development and deployment, it ensures a better scalabil-ity than the traditional software.
6. **High availability:** SaaS services ensure the 99.99% availability of user data as proper backup and recovery mechanisms are implemented at the back end.
7. **API integration:** SaaS services have the capability of integrating with other software or service through standard APIs.

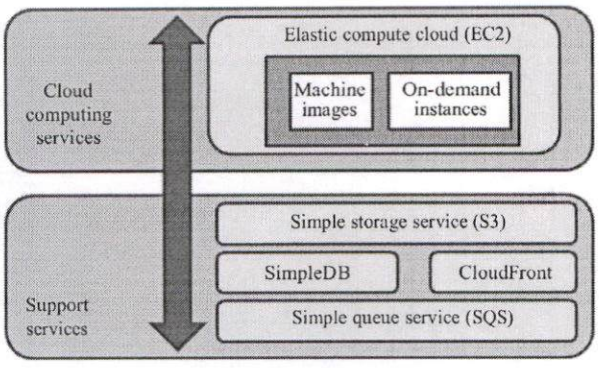
4) Define cloud service providers? which are the major cloud service providers?

Cloud service providers are companies that establish public clouds, manage private clouds, or offer on-demand cloud computing components (also known as cloud

computing services) like Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service(SaaS). Cloud services can reduce business process costs when compared to on-premise IT.

- Amazon Web Services (AWS)
- Microsoft Azure
- Google Cloud Platform (GCP)
- IBM

5) Describe the support services offered by amazon web services?



Support services:

- Simple storage service(s3)
- SimpleDB
- CloudFront
- Simple queue service(sqs)

6) A) Describe several approaches of cloud migration and list the phases of cloud migration?

Approaches of cloud migration:

The following are the four broad approaches for cloud migration that have been adopted effectively by vendors:

1. **Migrate existing applications**: Rebuild or rearchitect some or all the applications, taking advantage of some of the virtualization technologies around to accelerate the work. But, it requires top engineers to develop new functionality. This can be achieved over the course of several releases with the timing determined by customer demand.
2. **Start from scratch**: Rather than cannibalize sales, confuse customers with choice, and tie up engineers trying to rebuild existing application, it may be easier to start again. Many of the R&D decisions will be different now, and with some of the more sophisticated development environments, one can achieve more even with a small focused

working team.

3. **Separate company**: One may want to create a whole new company with separate brand, management, R&D, and sales. The investment and internet protocol (IP) may come from the existing company, but many of the conflicts disappear once a new *born in the cloud* company is established. The separate company may even be a subsidiary of the existing company. What is important is that the new company can act, operate, and behave like a cloud-based start-up.
4. **Buy an existing cloud vendor**: For a large established vendor, buying a cloud-based competitor achieves two things. Firstly, it removes a competitor, and secondly, it enables the vendor to hit the ground running in the cloud space. The risk of course is that the innova- tion, drive, and operational approach of the cloud-based company are destroyed as it is merged into the larger acquirer.

Phases of cloud migration:

1. **Evaluation**: Evaluation is carried out for all the components like current infrastructure and application architecture, environment in terms of compute, storage, monitoring, and management, SLAs, operational processes, financial considerations, risk, security, compliance, and licensing needs are identified to build a business case for moving to the cloud.
2. **Migration strategy**: Based on the evaluation, a migration strategy is drawn—a hotplug strategy is used where the applications and their data and interface dependencies are isolated and these applications can be operationalized all at once. A fusion strategy is used where the applications can be partially migrated; but for a portion of it, there are dependencies based on existing licenses, specialized server requirements like mainframes, or extensive interconnections with other applications.
3. **Prototyping**: Migration activity is preceded by a prototyping activity to validate and ensure that a small portion of the applications are tested on the cloud environment with test data setup.
4. **Provisioning**: Premigration optimizations identified are implemented. Cloud servers are provisioned for all the identified environments, necessary platform softwares and applications are deployed, configurations are tuned to match the new environment sizing, and databases and files are replicated. All internal and external integration points are properly configured. Web services, batch jobs, and operation and management software are set up in the new environments.
5. **Testing**: Postmigration tests are conducted to ensure that migration has been successful. Performance and load testing, failure and recovery testing, and scale-out testing are conducted against the expected traffic load and resource utilization levels.

6) B) Explain the drawbacks of a web application?

- There are several types of applications. The first type of applications that was devel- oped and used was a stand-alone application.

- A stand-alone application is developed to be run on a single system that does not use network for its func-tioning.

- These stand-alone systems use only the machine in which they are installed. The functioning of these kinds of systems is totally dependent on the resources or features available within the system.
- These systems do not need the data or processing power of other systems; they are self-sustaining. But as the time passed, the requirements of the users changed and certain applications were required, which could be accessed by other users away from the systems.
- This led to the inception of web application.
  - The web applications were different from the stand-alone applicationsin many aspects.
  - The main difference was the client server architecture that was followed by the web application. Unlike stand-alone applica- tions, these systems were totally dependent on the network for its work- ing.
  - Here, there are basically two components, called as the client and the server. The server is a high-end machine that consists of the web appli- cation installed. This web application is accessed from other client sys-tems. The client can reside anywhere in the network. It can access the web application through the Internet.
  - This type of application was very useful, and this is extensively used from its inception and now has become an

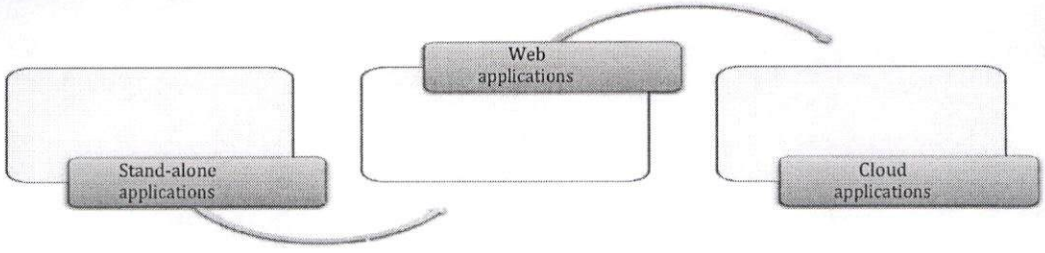


FIGURE 3.3

Computer application evolution.

important part of day-to-day life. Though this application is much used, there are shortcomings as discussed in the following:

- The web application is not elastic and cannot handle very heavy loads, that is, it cannot serve highly varying loads.
- The web application is not multitenant.
- The web application does not provide a quantitative measurement of the services that are given to the users, though they can monitor the user.

- The web applications are usually in one particular platform.
- The web applications are not provided on a pay-as-you-go basis; thus, a particular service is given to the user for permanent or trial use and usually the timings of user access cannot be monitored.
- Due to its nonelastic nature, peak load transactions cannot be handled.

Primarily to solve the previously mentioned problem, the cloud applicationswere developed.

7) A) Write short notes on pros and cons of IaaS and SaaS?

- **Pros and Cons of IaaS:**

Being one of the important service models of cloud computing, IaaS provides lot of benefits to the IT users. The following are the benefits provided by IaaS:

1. **Pay-as-you-use model**: The IaaS services are provided to the customerson a pay-per-use basis. This ensures that the customers are requiredto pay for what they have used. This model eliminates the unneces-sary spending on buying hardware.
2. **Reduced TCO:** Since IaaS providers allow the IT users to rent the com-puting resources, they need not buy physical hardware for running their business. The IT users can rent the IT infrastructure rather thanbuy it by spending large amount. IaaS reduces the need for buying hardware resources and thus reduces the TCO.
3. **Elastic resources**: IaaS provides resources based on the current needs.IT users can scale up or scale down the resources whenever they want. This dynamic scaling is done automatically using some load balancers. This load balancer transfers the additional resource request to the new server and improves application efficiency.
4. **Better resource utilization**: Resource utilization is the most important criteria to succeed in the IT business. The purchased infrastructure should be utilized properly to increase the ROI. IaaS ensures better resource utilization and provides high ROI for IaaS providers.
5. **Supports Green IT**: In traditional IT infrastructure, dedicated servers are used for different business needs. Since many servers are used, the power consumption will be high. This does not result in Green IT. In IaaS, the need of buying dedicated servers is eliminated as single infrastructure is shared between multiple customers, thus reducing the number of servers to be purchased and hence the power consumption that results in Green IT.

- **Pros and Cons of SaaS:**

SaaS applications are used by a wide range of individuals and start-up industries for its cost-related benefits. Apart from the cost-related benefits, SaaS services provide the following benefits:

1. **No client-side installation:** SaaS services do not require client-side installation of the software. The end users can access the services directly from the service provider data center without any instal- lation. There is no need of high-end hardware to consume SaaS

   services. It can be accessed from thin clients or any handheld devices,thus reducing the initial expenditure on buying high-end hardware.
2. **Cost savings:** Since SaaS services follow the utility-based billing or pay-as-you-go billing, it demands the end users to pay for what they have used. Most of the SaaS providers offer different sub- scription plans to benefit different customers. Sometimes, the generic SaaS services such as word processors are given for free to the end users.
3. **Less maintenance:** SaaS services eliminate the additional overhead of maintaining the software from the client side. For example, in the traditional software, the end user is responsible for performing bulkupdates. But in SaaS, the service provider itself maintains the auto- matic updates, monitoring, and other maintenance activities of the applications.
4. **Ease of access:** SaaS services can be accessed from any devices if itis connected to the Internet. Accessibility of SaaS services is not restricted to any particular devices. It is adaptable to all the devices as it uses the responsive web UI.
5. **Dynamic scaling:** SaaS services are popularly known for elastic dynamic scaling. It is very difficult for on-premise software to pro- vide dynamic scaling capability as it requires additional hardware. Since the SaaS services leverage elastic resources provided by cloud computing, it can handle any type of varying loads without disrupt-ing the normal behavior of the application.
6. **Disaster recovery:** With proper backup and recovery mechanisms, rep-licas are maintained for every SaaS services. The replicas are distrib-uted across many servers. If any server fails, the end user can accessthe SaaS from other servers. It eliminates the problem of single pointof failure. It also ensures the high availability of the application.
7. **Multitenancy**: Multitenancy is the ability given to the end users to share a single instance of the application. Multitenancy increases resource utilization from the service provider side.

Even though SaaS services are used by many individuals and start-up indus-tries, the adoption from the large industries is very low. The major problem with SaaS services is security to the data. All companies are worried about the security of their data that are hosted in the service provider data center.

7) B) Explain in detail about the overview of IaaS and SaaS with suitable diagram?

Overview of IaaS:

- IaaS changes the way that the compute, storage, and networking resources are consumed. In traditional data centers, the computing power is con- sumed by having physical access to

the infrastructure. IaaS changes the computing from a physical infrastructure to a virtual infrastructure.

- IaaS provides virtual computing, storage, and network resources by abstract-ing the physical resources. Technology *virtualization* is used to providethe virtual resources.
- All the virtual resources are given to the virtual machines (VMs) that are configured by the service provider.
- The end users or IT architects will use the infrastructure resources in the form of VMs as shown in Figure 5.4.
    - The targeted audience of IaaS is the IT architect. The IT architect can design virtual infrastructure, network, load balancers, etc., based on their needs. The IT architects need not maintain the physical servers as it is

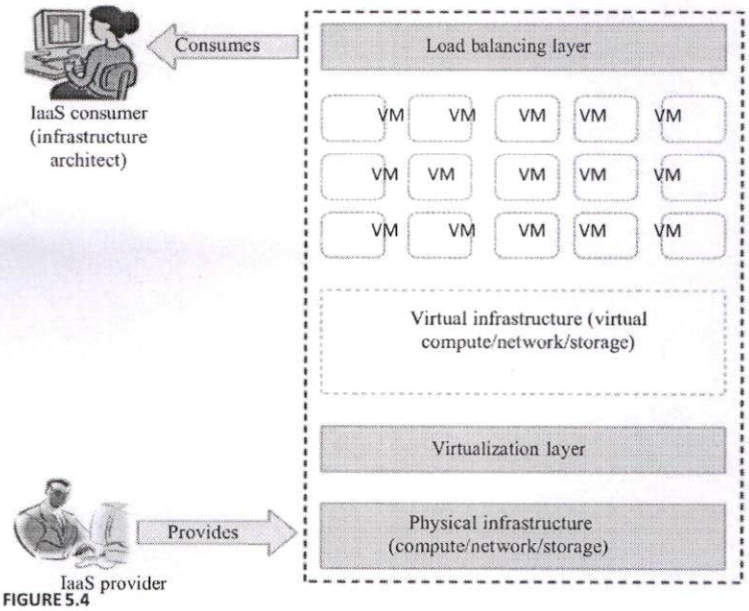
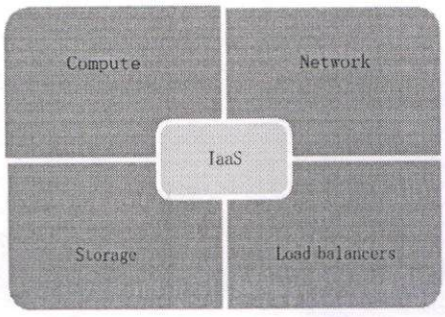


FIGURE 5.4

Overview of IaaS.



Services provided by IaaS providers.

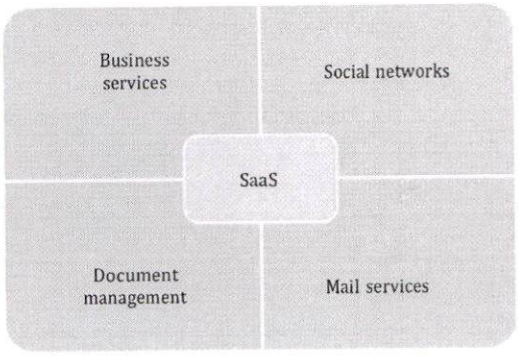
maintained by the service providers.

The physical infrastructure can be maintained by the service providers themselves. Thus, it eliminates or hides the complexity of maintaining the physical infrastructure from theIT architects. A typical IaaS provider may provide the flowing services as shown in Figure :

1. **Compute**: Computing as a Service includes virtual central processing units (CPUs) and virtual main memory for the VMs that are provisioned to the end users.
2. **Storage**: STaaS provides back-end storage for the VM images. Some of the IaaS providers also provide the back end for storing files.
3. **Network**: Network as a Service (NaaS) provides virtual networking components such as virtual router, switch, and bridge for the VMs.
4. **Load balancers**: Load Balancing as a Service may provide load balancing capability at the infrastructure layer.

Overview of SaaS:

- SaaS changes the way the software is delivered to the customers. In the traditional software model, the software is delivered as a license-based productthat needs to be installed in the end user device.
- Since SaaS is delivered as anon-demand service over the Internet, there is no need to install the softwareto the end user's devices.
- SaaS services can be accessed or disconnected at any time based on the end user's needs. SaaS services can be accessed from any lightweight web browsers on any devices such as laptops, tablets, and smartphones.
- Some of the SaaS services can be accessed from a thin client that does not contain much storage space and cannot run much software likethe traditional desktop PCs.
- The important benefits of using thin clients for accessing the SaaS application are as follows: it is less vulnerable to attack, has a longer life cycle, consumes less power, and is less expensive.
- A typical



FIGURE

Services provided by SaaS Providers.

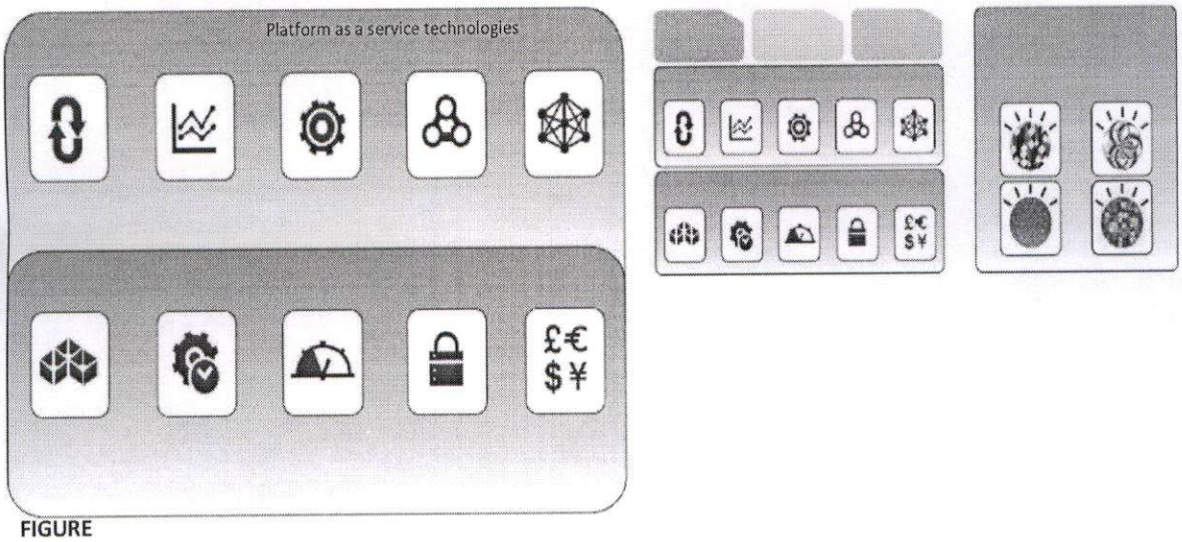
SaaS provider may provide business services, social networks, document management, and mail services as shown in Figure:

1. **Business services:** Most of the SaaS providers started providing a vari-ety of business services that attract start-up companies. The business SaaS services include ERP, CRM, billing, sales, and human resources.
2. **Social networks:** Since social networking sites are extensively usedby the general public, many social networking service providers adopted SaaS for their sustainability. Since the number of users of the social networking sites is increasing exponentially, cloud com- puting is the perfect match for handling the variable load.
3. **Document management**: Since most of the enterprises extensively useelectronic documents, most of the SaaS providers started provid- ing services that are used to create, manage, and track electronic documents.
4. **Mail services**: E-mail services are currently used by many people. Thefuture growth in e-mail usage is unpredictable. To handle the unpre-dictable number of users and the load on e-mail services, most of the e-mail providers started offering their services as SaaS services.

8) A) Discuss about the services offered by IBM Smart cloud?

- IBM SmartCloud is a branded ecosystem of cloud computing productsand solutions from IBM.
- It includes IaaS, SaaS, and PaaS offered through public, private, and hybrid cloud delivery models.
- IBM places these offerings under three umbrellas: SmartCloud Foundation, SmartCloud Services, and SmartCloud Solutions.
- Figure briefly explains the architecture of IBM SmartCloud.
- SmartCloud Foundation consists of the infrastructure, hardware, provisioning, management, integration, and security that serve as the underpinnings of a private or hybrid cloud. Built using those founda- tional components, PaaS, IaaS, and backup services make up SmartCloud Services.
- Running on this cloud platform and infrastructure, SmartCloud Solutions consist of a number of collaboration, analytics, and marketing SaaS applications.

- Along with IaaS, PaaS, and SaaS, IBM also offers Business Process as a Service (BPaaS). Infrastructure cloud services provide the consumer the pro- vision of processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.
- In platform cloud services, a consumer can deploy consumer-created or consumer-acquired applications onto the cloud infrastructure created using programming languages and tools supported by the provider.
- Application cloud services allow consumers to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-basede-mail).
- Business process cloud services are any business process (horizon- tal or vertical) delivered through the cloud service model (multitenant, self-service provisioning, elastic scaling, and usage metering or pricing) via the Internet with access via web-centric interfaces and exploiting web-oriented cloud architecture.
- The BPaaS provider is responsible for the related busi- ness functions.



FIGURE

Architecture of IBM SmartCloud. (Adapted from Transitioning to IBM smart cloud notes, Smart Cloud White Paper-IBM.)

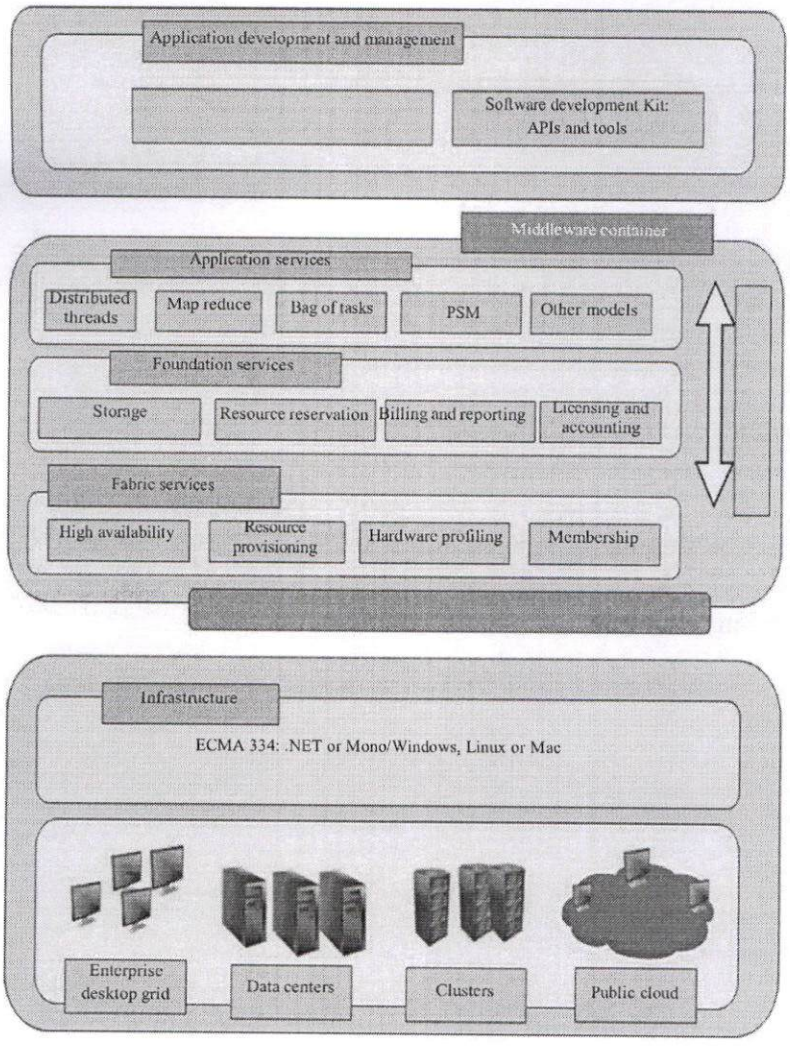
IBM SmartCloud foundation

8) B) Describe the overview of Aneka platform with suitable diagram?

Aneka provides a set of services that make enterprise cloud construction and development of applications as easy as possible without sacrificing flexibil- ity, scalability, reliability, and extensibility.

Figure gives an overview of the Aneka platform. The key features sup-ported by *Aneka* are as follows:

1. A configurable and flexible execution platform (container) enabling plug-gable services and security implementations. Multiple authentication/authorization mechanisms such as role-based security and Windows domain–based authentication are considered for this purpose.
2. Multiple persistence options including Relational Database Manage- ment System (RDBMS), Structured Query Language (SQL) Express,MySQL, and flat files.
3. Software development kit (SDK) supporting multiple programming models including object-oriented thread model, task model for legacyapplications, and MapReduce model for data-intensive applications.
4. Custom tools such as Design Explorer for parameter sweep studies.



FIGURE

Overview of the Aneka platform. (Adapted from http://www.manjrasoft.com/aneka_ architecture.html, accessed January 8, 2013.)

Easy to use management tool for SLA and Quality of Service (QoS)negotiation and dynamic resource allocation.

1. Supports deployment of applications on private or public clouds inaddition to their seamless integration.

Aneka allows servers and desktop PCs to be linked together to form a very powerful computing infrastructure. This allows companies to become energy efficient and save money without investing in a number of computersto run their complex applications.

Each *Aneka* node consists of a configurable container that includes infor- mation and indexing, scheduling, execution, and storage services. *Aneka* supports multiple programming models, security, persistence, and commu-nications protocols.

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KANDLAKOYA, MEDCHAL ROAD, HYDERABAD-501 401

ASSESSMENT OF COURSE OUTCOMES (INTERNAL EXAMINAION)

PROGRAMME B.TECH (CSE)

YEAR IV **SEM** VII **Academic Year** 2022-23 **BATCH** 2019-2023

Course Code A30542 **Course Name** Cloud Computing

CO TARGET %	
>= 50	<50
Y	N

ATTAINMENT TARGET %		
>= 65	<=65 & >55	<55
3	3	1

COURSE OUTCOMES ATTAINMENT

QUESTIONS	Q11, MID 01	Q12, MID 01	Q13, MID 01	Q11, MID 02	Q12, MID 02	Q13, MID
CO	CO1	CO2	CO3	CO3	CO4	CO5
No of Students attempted	87	94	86	93	93	80
Number of students attained	70	80	67	62	80	49
CO Attainment %	**80.46%**	**85.11%**	**77.91%**	**66.67%**	**86.02%**	**61.25%**
Average CO Attainment %	**CO1**	**CO2**	**CO3**		**CO4**	**CO5**
	80.46%	**85.11%**	**72.07%**		**86.02%**	**61.25%**
Attainment Level	**3**	**3**	**3**		**3**	**2**

(Course Coordinator)

(Programme Coordinat

DATA FOR EVALUATION OF COURSE OUTCOMES (INTERNAL EXAMINATIONS) - Cloud Computing

S.No	H.No	Q11, MID 01			Q12, MID 01			Q13, MID 01			Q11, MID 02			Q12, MID 02			Q13, MID	
		CO1			CO2			CO3			CO3			CO4			CO5	
		5	%	AT	5	%	AT	5	%	AT	5	%	AT	5	%	AT	5	%
1	18H51A0524	0.5	10%	N	0.5	10%	N				2.5	50%	Y	3	60%	Y	3	60%
2	18H51A0558				1.5	30%	N				0.5	10%	N				2	40%
3	18H51A0589							0.5	10%	N								
4	18H51A05E0				3	60%	Y	3	60%	Y	1	20%	N	2	40%	N		
5	18H51A05F6	3.5	70%	Y	4.5	90%	Y	2.5	50%	Y	4	80%	Y	4	80%	Y	4	80%
6	18H51A05J4										2.5	50%	Y	1	20%	N	1.5	30%
7	18H51A05L1																	

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KANDLAKOYA, MEDCHAL ROAD, HYDERABAD-501 401

ASSESSMENT OF COURSE OUTCOMES

PROGRAMME **B.TECH (CSE)**

YEAR IV SEM VII Academic Year 2022-23 BATCH *2019-2023*

Course Code A30542 Course Name Cloud Computing

ASSESSMENT OF COURSE OUTCOMES THROUGH EXTERNAL EXAMINAION MARKS

CO TARGET VALUES	
>= 50	<50
Y	N

ATTAINMENT TARGET %		
>= 65	<=65 &>55	<55
3	2	1

COURSE OUTCOMES ATTAINMENT

CO	CO1	CO2	CO3	CO4	CO5
No of Students attempted	51	51	51	51	51
Number of students attained	27	33	32	24	17
CO Attainment %	52.94%	64.71%	62.75%	47.06%	33.33%
Attainment Level	1	2	2	1	1

ASSESSMENT OF COURSE OUTCOMES THROUGH INTERNAL EXAMINAION MARKS

CO TARGET VALUES	
>= 50	<50
Y	N

ATTAINMENT TARGET %		
>= 65	<=65 &>55	<55
3	3	1

COURSE OUTCOMES ATTAINMENT

CO	CO1	CO2	CO3	CO4	CO5
No of Students attempted	87	94	86	93	93
Number of students attained	70	80	67	62	80
CO Attainment %	80.46%	85.11%	72.07%	86.02%	61.25%
Attainment Level	3	3	3	3	2

BOOKLET NUMBER :		CSE - Sec - B College Stamp	R18

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MID SEMESTER EXAMINATION ANSWER BOOK

Registered No. | 2 | 0 | H | 5 | 1 | A | 0 | 5 | N | 0 |

FIRST / SECOND SEMESTER EXAMINATION B.Tech./M.Tech./MBA VII Semester 6/11/2023 (Month and year)

Subject : Cloud Computing (PE-V)

Date : 10/11/2023 Signature of the Invigilator with date

INSTRUCTIONS TO THE CANDIDATES

1. This booklet contains 16 pages. Candidates must ensure it before writing and in case a defective answer book is issued it must be returned to the invigilator and a new and defect free booklet must be obtained.
2. Before the candidate begins to answer, registered number, particulars of year, semester, subject etc., are to be filled in. Failure to enter all or any of these particulars may disqualify the paper from valuation.
3. Candidate is prohibited from
   (a) Writing.
   ☞ anything addressing the examiner in any manner whatsoever, in their answer book.
   ☞ Objectionable/obscene language in the answer book.
   ☞ anything other than their Registered Number on the question paper.
   (b) either seeking or providing any assistance to the fellow candidates in the exam.
   (c) possessing a manuscript or a printed matter, in any form, in the examination hall.
   (d) bringing loose sheets or paper into the examination hall and detaching any paper from the answer book.
   (e) carrying Mobile Phone to Exam Hall.
   Violation of these instructions will be viewed as a case of malpractice, which is a punishable offence.
4. Before beginning to answer any question, candidates must write the correct question number, in the margin only and should not write anything else in the margin.
5. Answers must be written legibly on both sides of the paper. There shall be about 25 lines in each page. It is not necessary to begin each answer on a fresh page. Candidates should not use any other ink, except BLACK or BLUE ink.
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10. **No additional answer books will be supplied.**

To be filled in by the Examiner only

PART - A / PART - B

MARKS SLIP

	Q.No.	1	2	3	4	5	—	—	—	—	—	Part-A Total
PART-A	Marks	2	2	2	2	2						10
	Q.No.	6		7		8	—	—	—	—	—	Part-B Total
		A	B	A	B	A	B					
PART-B	Marks	5			5	4						14
Grand Total in Words : TWO-FOUR										GRAND TOTAL		24

Signature of the Scrutinizer with Date

18/11/23
Signature of the Examiner with Date

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Part-A

1. SLAs (Service Level Agreements)

Serivce level Agreement (SLAs) is a important agreement in the cloud computing. It is a agreement between the service provider and consumer.

importance of SLAs in Cloud Computing

1. it provide the communication & relationship between the service provider and consumer
2. it manage the contract between them to provide & manage the phone calls, requirements.
3. provide the Quality and performance of the service to the Consumer
4. It can make the clear agreement between them to need not worry about the service between the service provider and consumer

2. Infrastructure as a Service (Iaas)

- Infrastructure as a service is a cloud service model in the cloud computing.
- Iaas changes the way to consume, compute, storage and networking are consumed.
- Iaas provides the infrastruce as a service to the IT architects.
- Infrastructure as a service generally used in the company like Aws, microsoft Azure, red hat etc...

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3. characteristics of Paas

platform as a service (Paas) consist of the following characteristics.

1. web access
2. offline access
3. Inbuilt Scalability
4. centralized optimization

these are the some of the characteristics of the platform as the service which can change the way to developers can develop deploy the service provided by the service provider.

Characteristics of Saas

Software as a service (Saas) consist of the following characteristics.

1. one to many
2. web access
3. high availability
4. better Scalability
5. centralized optimization

These are the some of the characteristics of the Software as a Service which can change the way to software is delievered to the end user.

4. Cloud Service providers.

Cloud Service providers are the companies which are efficiently using the services provided by the cloud computing. these cloud service providers are service providers who can use, improve and implement the cloud as the service.

Major cloud service providers.

The major cloud service providers are the ~~Amazon~~.

1. ~~Amazon~~ (AWS)
2. Google (Google apps)
3. IBM (IBM Cloud)
4. Redhat
5. Yahoo
6. Microsoft (microsoft Azure, microsoft 365)

5. Support services offered by ~~Amazon~~ web services

~~Amazon~~ web service is a major cloud service provider which developed by the ~~Amazon~~. There are 2 service offered by Aws are two types

1. Cloud computing service
2. Support service

Now, Support service offered by the ~~Amazon~~ web services are

1. Simple Queue Service (SQS)
2. Simple Storage Service (S3)
3. Simple DB
4. Cloud Front

These are the support services which offered by the Aws (Amazon web service)

part-B

6A. Approaches of cloud migration

Cloud migration consist of mainly four approaches they are

1. migrated existing cloud/Strategy
2. Start from Scratch
3. Seperate Company
4. Buying existing Cloud Vendors.

1. migrated existing application.

migrated existing application is a traditional approaches which was followed for the cloud migration. which can change its traditional approach to Cloud Computing ways to apply those to virtual migration to cloud migration. It is a composite & Complex approach to maintain

2. Start from Scratch

Start from Scratch is a approach which can start the cloud migration from its basics and build the individual computing skills. Start from Scratch is used mainly in the start-up company and individuals who are intrested in the cloud migration of the Cloud Computing

3. seperate Company

seperate Company is a approach which cannot migrated existing application of their Company to the company which start from Scratch. They maintain the cloud computing technology in the seperate company to donot effect their applications of process

4. Buying existing cloud vendors

Buying existing cloud vendors is a most popular approach of cloud migration, in that a company is buying the a well known, knowledge and expert vendor of cloud for theee company This can help in two different aspect i.e. redu

1. reduce the competitors
2. improve the growth of cloud migration.

Phases of cloud migration.

Following is the list of the phases of cloud migration in the cloud computing

1. Evaluation
2. Migrating Strategy
3. prototyping
4. provisioning
5. Testing.

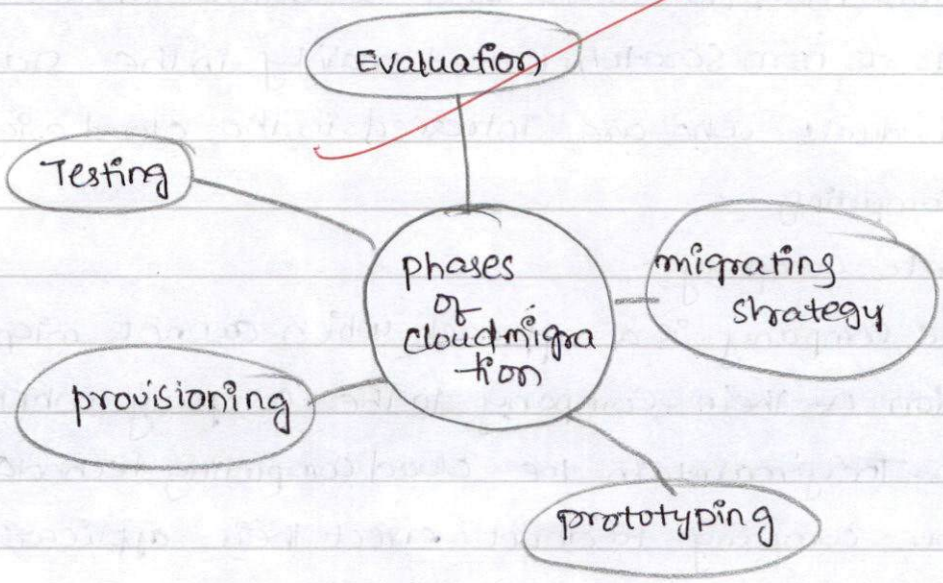


fig. phases of cloud migration.

7B. Overview of Iaas

- Infrastructure as a service is a cloud service model in the cloud Computing
- Infrastructure as a service is change the way to compute, Store, networking are consumed.
- Iaas provide the services to the IT architects
- Iaas is a cloud service which can manage the compute, storage, networking and load.
- In generally, Infrastructure can be used in the traditional manner as a on-demand service to manage and consume the compute, storage and networking.
- Virtualization technology is used to virtualize the infrastructure as a service for the architect
- This virtualizing provided to the virtual machine (VM).
- Virtual machine can implement and change the physical infrastructure to the virtual infrastructure
- Then these virtual infrastructure via virtual machine providing to the infrastructure as a service consumer (Iaas Consumer)
- we can overview the infrastructure as a service in the suitable diagram which can help to analyze and understand easily
- there are some companies which are using the Infrastructure as a service they are

1. Google Engine . 2. microsoft Azure 3. ETM etc.

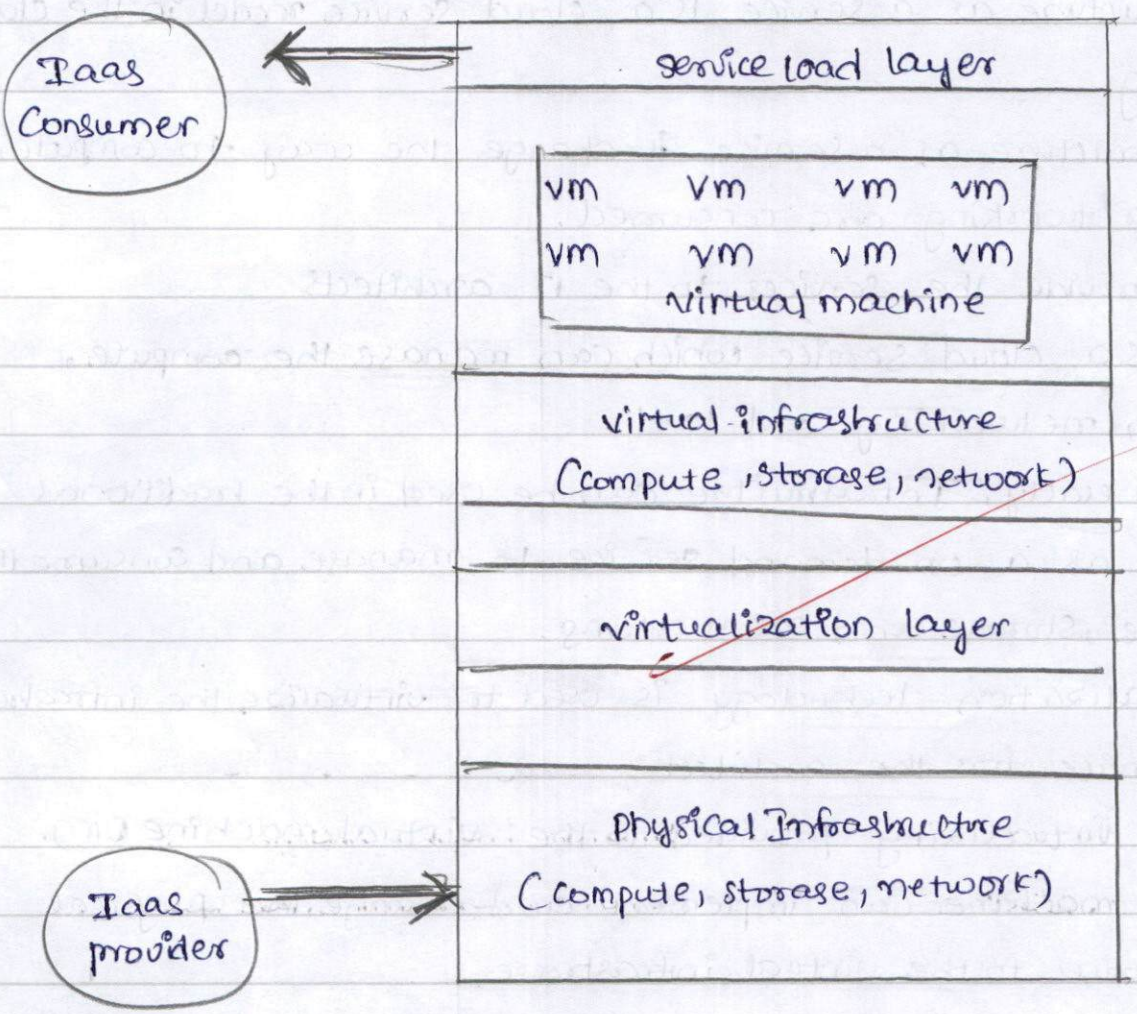


fig: overview of Iaas

overview of Saas

- software as a service is a cloud service model in the cloud computing
- software as a service is change the way how the software are is delievered to the end user and consumer.
- software as a service provide the service to the endusers and consumer.

- Saas is a service which can manage the process of delivering and deploying the service to the consumer
- In Generally, the traditional technology of the software as a service is a on-demand service over internet.
- By virtualizing the process of the service using cloud service technology is improve through Email, socically.
- software as a service change to virtual software service.
- It become very easy to saas consumer.
- saas providers can help to change the way to software delivered to the end user.
- Now, saas become very popular cloud service in the industry

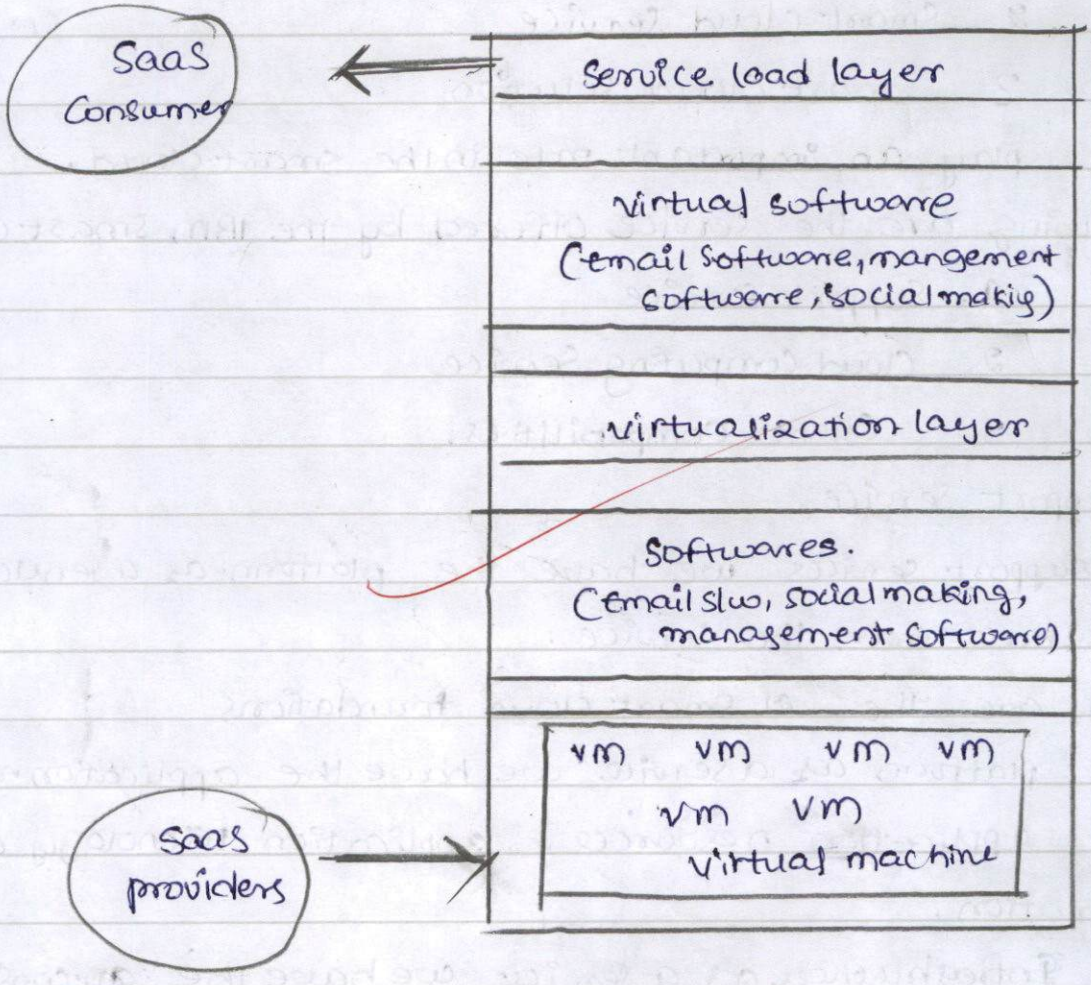


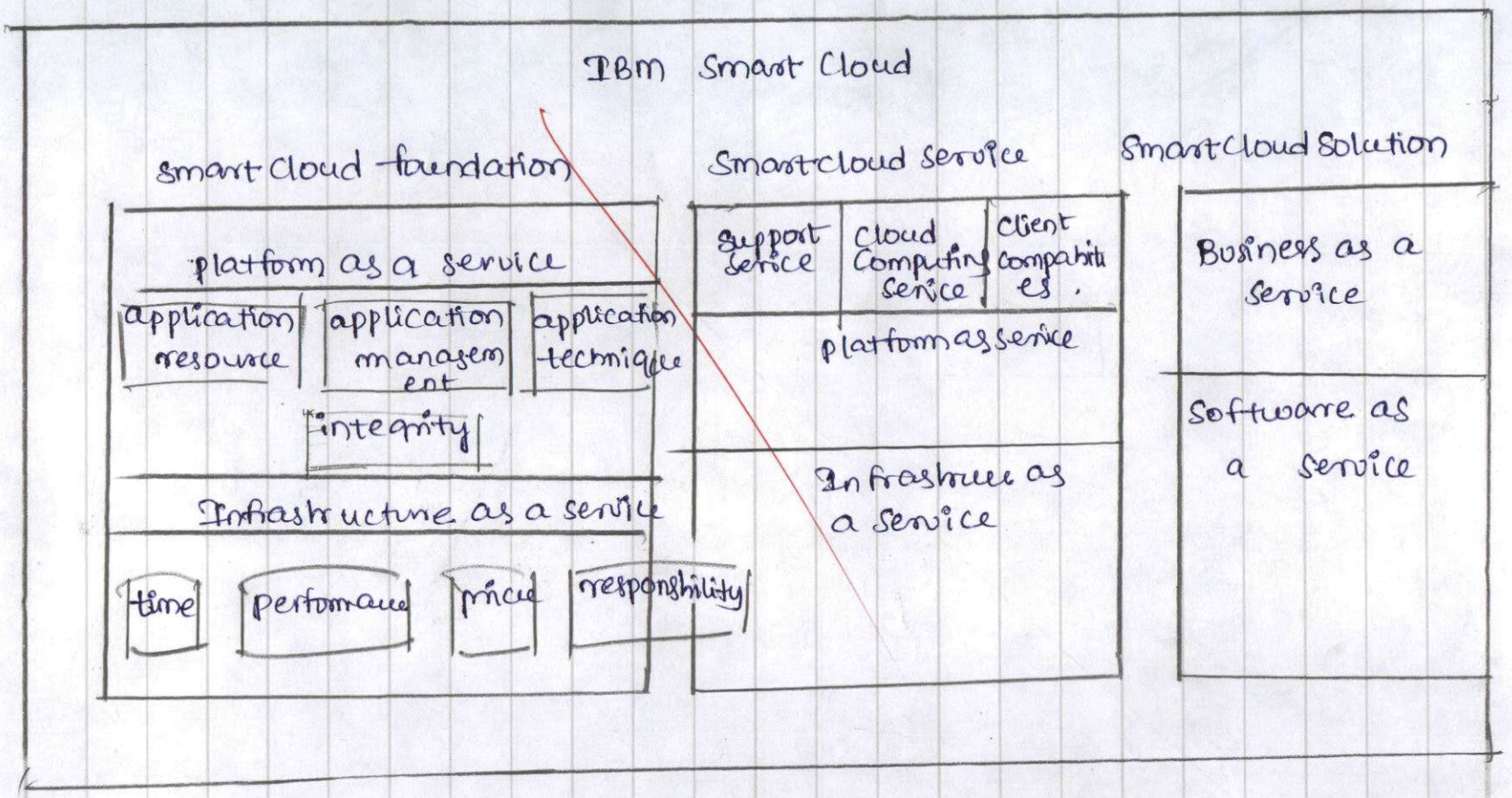
fig overview of Saas

8A IBM Smart Cloud

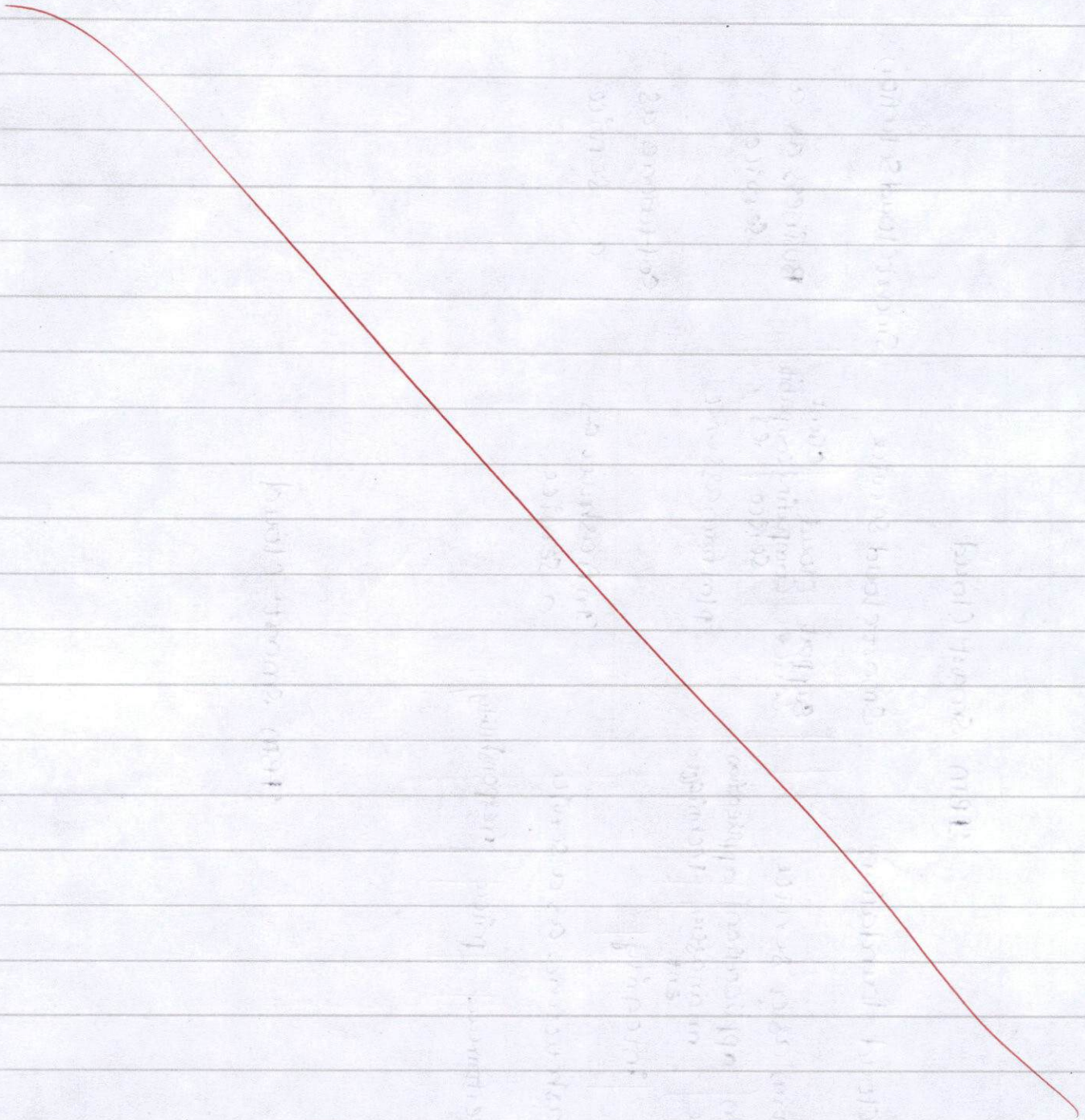
- IBM Smart cloud is a cloud Service provider,
- IBM Smart cloud is a branded ecosystem of the service provided by the IBM.
- IBM Smart cloud is a IBM cloud which can be implemented in the cloud service providers for the cloud service in Cloud computing
- IBM Smart Cloud can be the branded ecosystem which can deploy the models like private, public, community and hybrid cloud through the Iaas, paas and saas.
- These will affected and managed by the service providers.
- These can be managed in the three umbrella process.
    1. 1 Smart Cloud foundation
    2 Smart cloud service
    3 Smart cloud solution
- These play an important role in the smart cloud.
- following are the service offered by the IBM smart cloud
    1. Support service
    2. Cloud computing service
    3. Client compabilities.

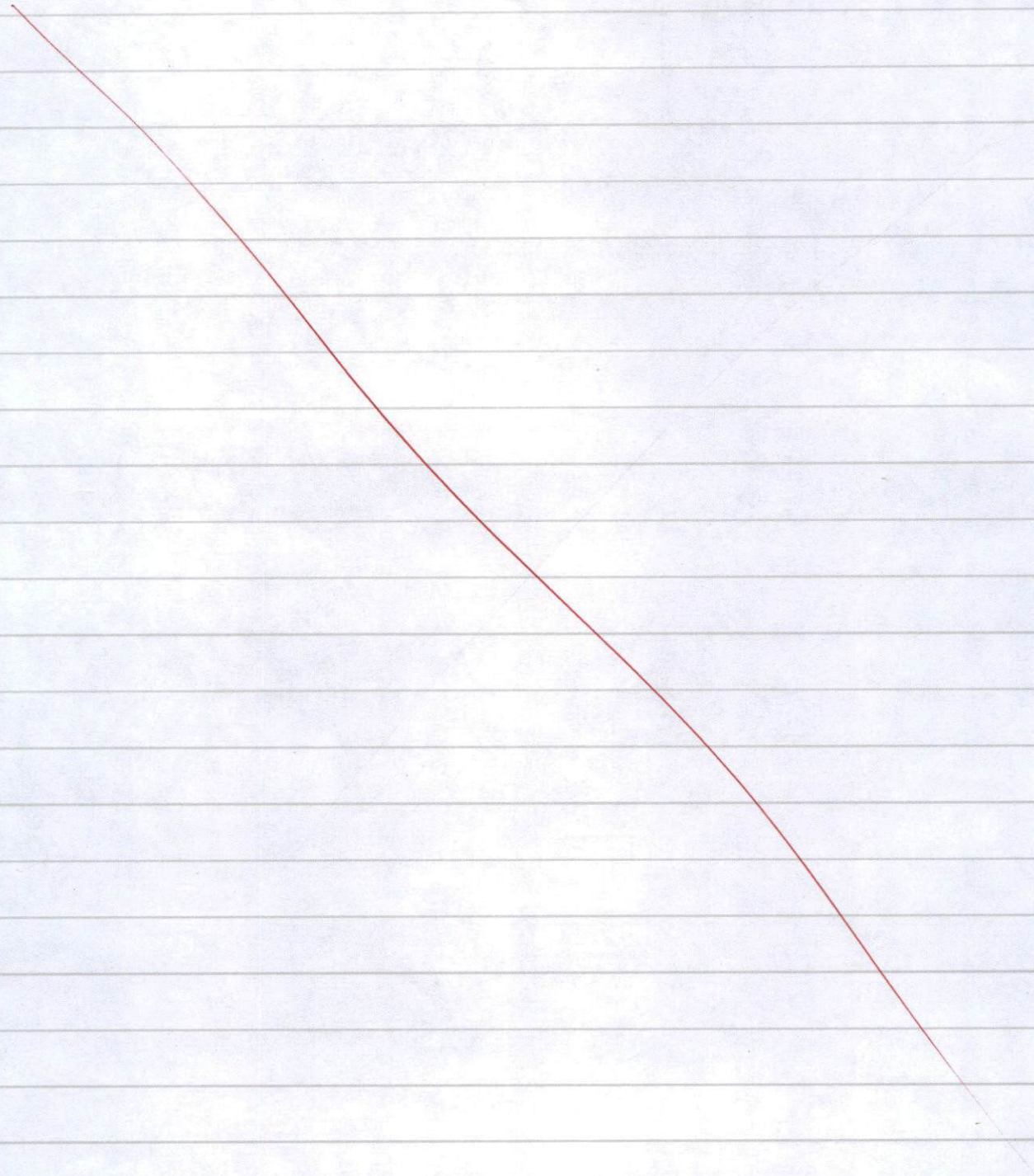
1. Support Service.

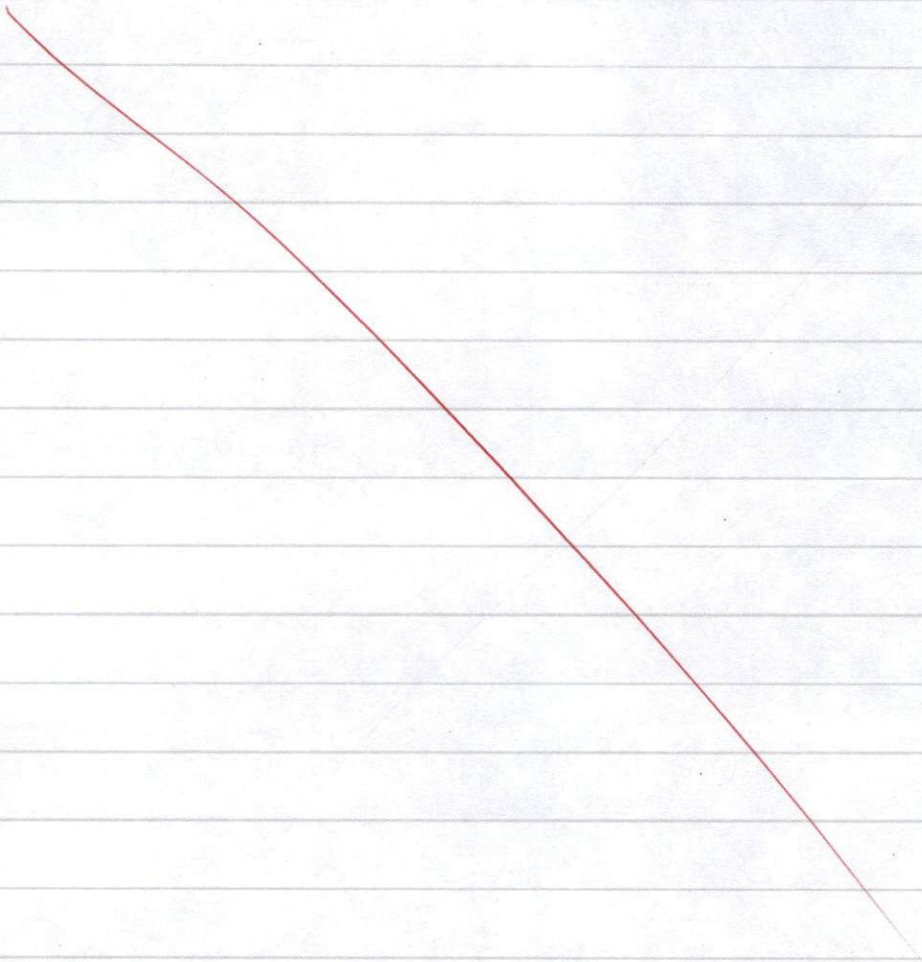
- In support services we have the platform as a service and Infrastructure as the service.
- This are the smart cloud foundations.
- In platform as a service we have the application management, application resources, application technology and integration.
- In Infrastructure as a service we have the consistency.

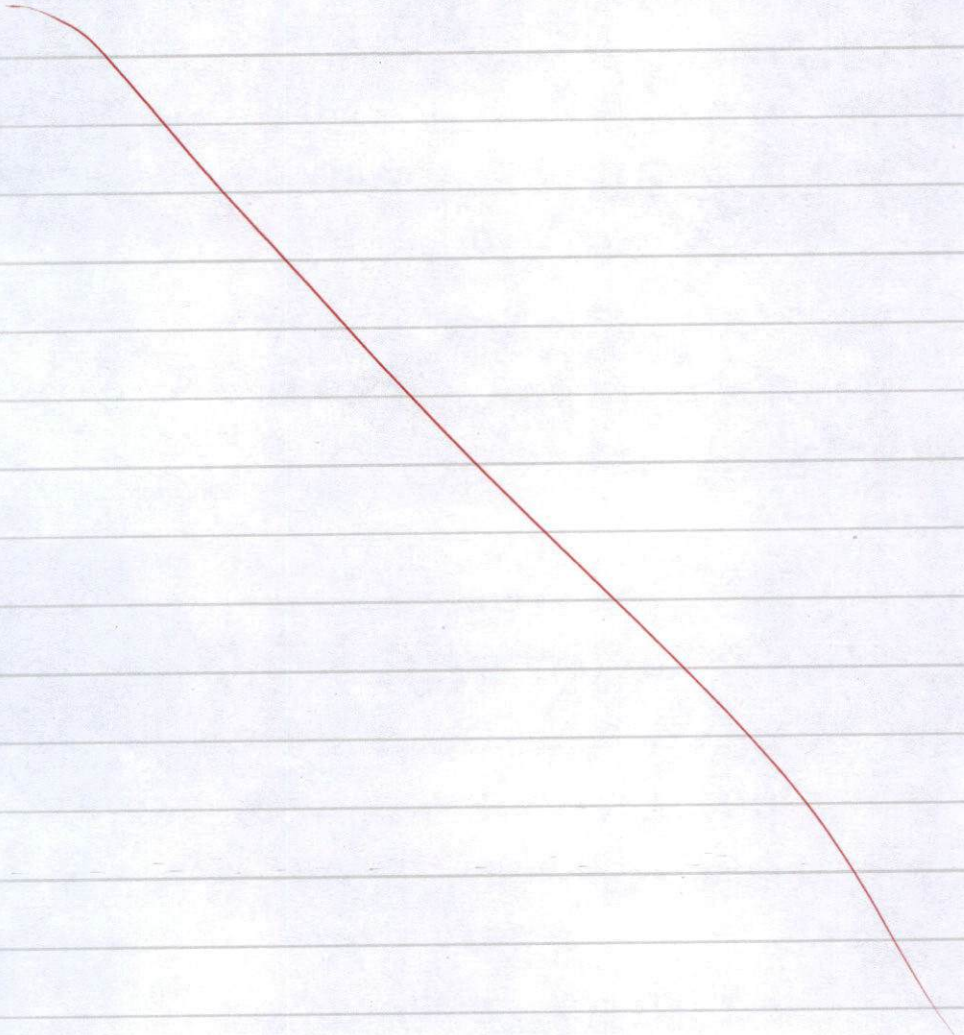


time and performance, price, compatabilities and etc..









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MID SEMESTER EXAMINATION ANSWER BOOK

Registered No. | 2 | 0 | H | 5 | 1 | A | 0 | 5 | 6 | 0 |

FIRST / SECOND SEMESTER EXAMINATION B.Tech./M.Tech./MBA VIIth Semester Sept-2023
(Month and year)

Subject : cloud computing

Date : 02/09/2023

Signature of the Invigilator with date

2/9/23

INSTRUCTIONS TO THE CANDIDATES

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   (b) either seeking or providing any assistance to the fellow candidates in the exam.
   (c) possessing a manuscript or a printed matter, in any form, in the examination hall.
   (d) bringing loose sheets or paper into the examination hall and detaching any paper from the answer book.
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PART - A / PART - B

MARKS SLIP

PART-A	Q.No.	1	2	3	4	5	—	—	—	—	—	Part-A Total
	Marks	1 1/2	2	2	1 1/2	2						9
PART-B	Q.No.	6		7		8		—	—	—	—	—	—	Part-B Total
		A	B	A	B	A	B							
	Marks	4 1/2		4 1/2		5								14
Grand Total in Words : Two-Three											GRAND TOTAL			23

5/9/23

Signature of the Scrutinizer with Date

Signature of the Examiner with Date

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Part A 5 X 2 = 10M

1A Grid computing :- It is a computing in which the group of systems or computers are in one network which are used to solve a problem which is difficult to solve by a single machine
→ it is used to solve computational problems. and increase the solving productivity

1/2

2A cloud computing :- cloud computing is the process of storing and accessing the information, data and applications like programs over the internet from the remote Location and device instead of users computer Hard drive

2

→ cloud is a metaphore on Internet
Ex :- AWS, Azure, Google cloud, Oracle cloud, Alibaba etc

3A Five essential characteristics of cloud.

1) on demand self service :-
Here the self service of the resources over the Internet are independently accessed by cloud users.

2) ubiquitious network access.
the cloud user can store and access the cloud from anywhere throughout the network.

3) Resource pooling :- multiple customers can share the resources among them using multi tenant model. This model allocates and deallocates the virtual and physical resources based on the demand

4) Rapid Elasticity :- This indicates that the system has the Ability to shrink and grow its storage & Memory properties. and it can allocates and deallocate the Memory accordingly in real time

5) Measured service :- The amount of storage used, The Number of transactions done, the amount of data used, based on these key points the charges are applied per hour to the user.

4A cloud computing is a platform, refers that it is a operating system and hardware of servers for a internet based datacenters, here both Hardware and software products co-exist remotely and at a scale.

5A Elasticity :- It is a process of shrink and grow of CPU, storage, memory based on the demand.

→ Elasticity in cloud computing is done very quickly in Real time.

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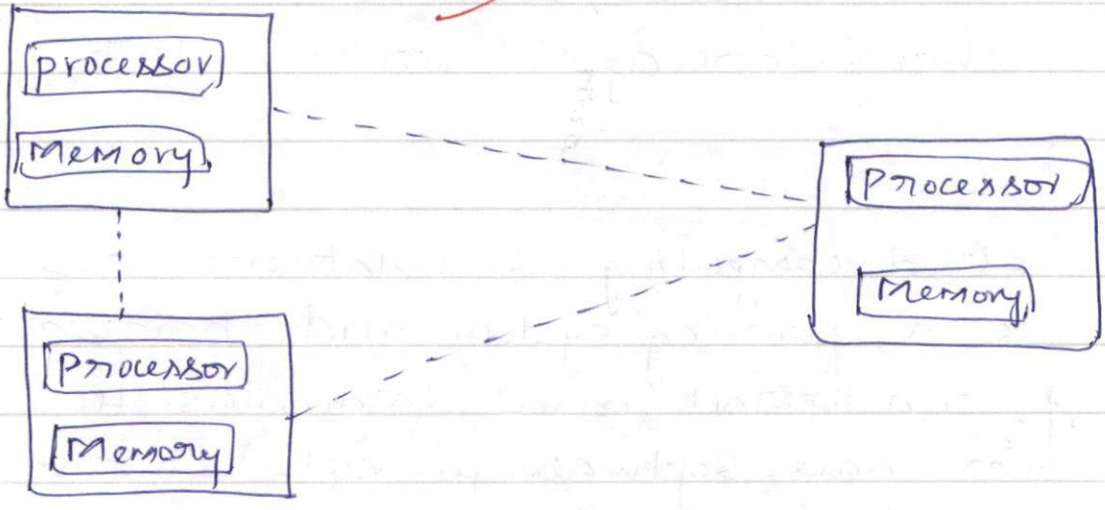
Part - B 3×5 = 15M

6A) Computer paradigms :- it is a technique of linking two or more systems or processors to solve a problem. These systems are linked through a network using (LAN) Local Area network, to support some basic functionalities to access some resources or services.

There are (5) Basic computer paradigms.

(1.) Distributed Computing :-



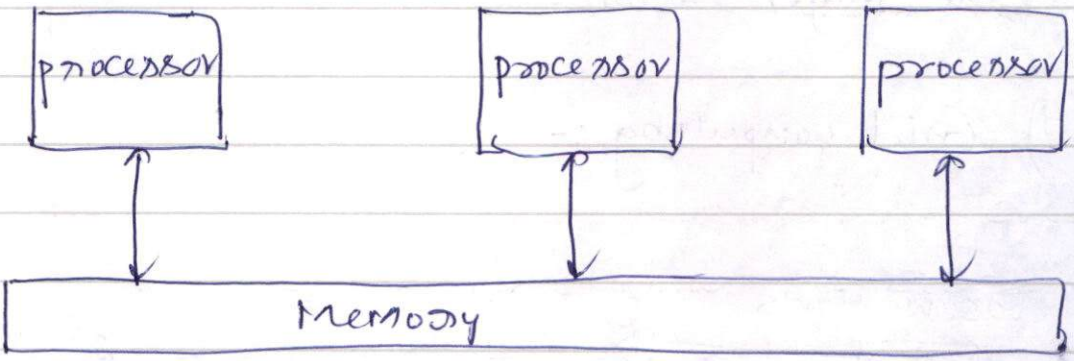
→ Here in this paradigm multiple systems are used to solve a single problem.

→ The problem is divided into subproblem and each subproblem is solved by each system

→ It is a solution for a problem where the RAM is too small and the data that should process is too big

→ it provides fault tolerance.

(2) parallel computing:-



→ Here multiple systems are linked together and they are used simultaneously.

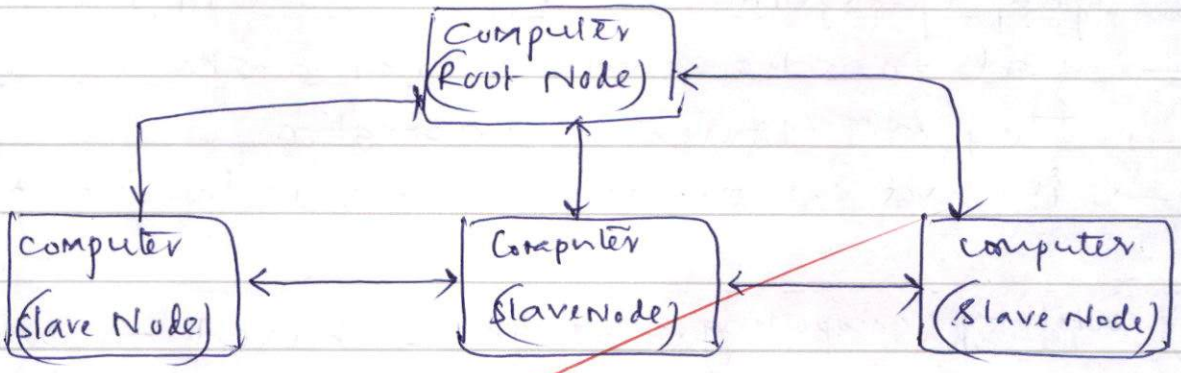
→ They are used to complex problems

→ They consume High power and they are concurrently worked

→ ~~cost of~~ Head-cost is High due to synchronisation and data transfer.

4 1/2

(3) cluster computing:-



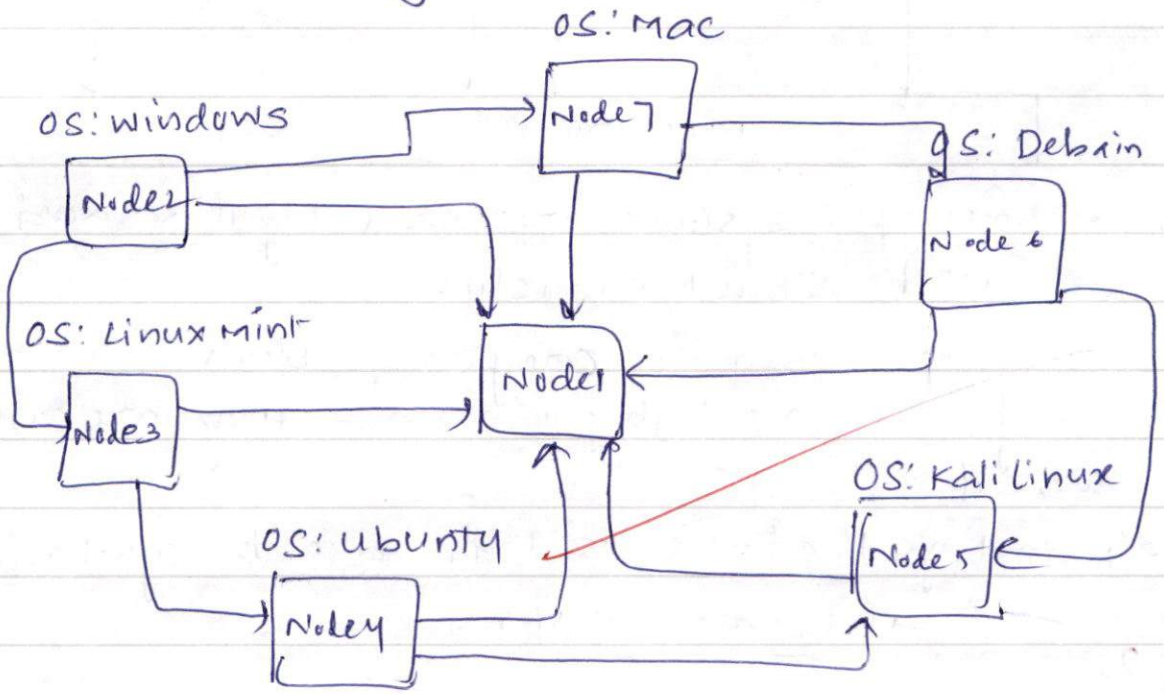
→ Here this uses Homogeneous machines

→ group of independent systems are used to solve problems.

→ They are formed using small networks

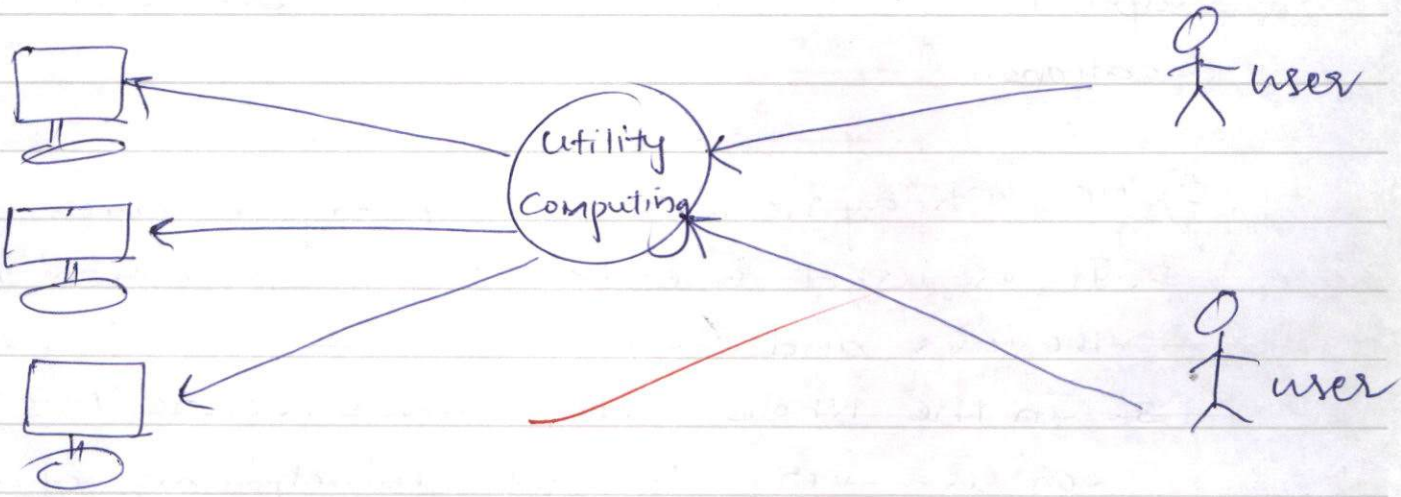
→ High Availability, Load Balancing, Expandability are the major Advantages of cluster computing

(4) Grid computing :-

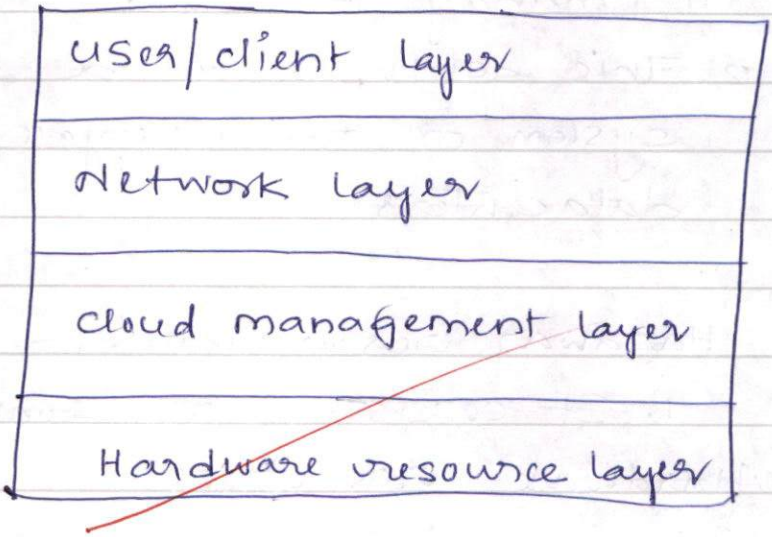


→ different operating systems are used in this computing
→ group of systems or computers are in one network
→ used to solve computational tasks
→ They are Efficient collaboration
→ it uses the existing systems in the better way

(5) utility computing :- → it is based on "pay as per use"
→ It consist of owner who provide utilities like services, storage and data to the customers. and charge based on the usage



8A.) Cloud Architecture :- Cloud architecture consists of 14) layers which describes everything about the cloud.



1.) user/client layer :- 1. It consist of users and clients

2. The clients can be thick clients, thin clients, mobiles or any Handheld devices which

Supports basic functionalities to access the web applications.

2). Network layer:- 1. It is very import layer
2. It is used to establish a connection between the user and cloud
3. In the whole cloud infrastructure this connection is very important which can offer the services to the customer.
4. It is primarily the internet

3) cloud management layer:-
1. It consists of a software which is used to manage the cloud
2. This software can be cloud operating system or the interface between the data centers

4) Hardware resource layer:-
1. It consists of provisions of actual Hardware resources
2. It is used the manage the physical resources of the cloud, including routers, servers, cooling and power framework
3. These are executed in data centers.

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4B) Deployment models in cloud:-

There are four deployment models in cloud

1. private deployment model
2. public deployment model
3. Hybrid deployment model
4. Community deployment model.

1) public :- 1. It is open to all.
2. pay as per use policy
3. open to all kinds of service in computing
4. used in government organization, Institutes
5. Less secured and Less data secure.
6. Ex :- AWS (EC2), Azure.
7. managed by thirdparty vendor

2). private :-
1. It is not open to all.
2. It is managed by the organization and only that particular organization can be used.
3. High secured and high data secure.
4. managed by the company or thirdparty vendor

4 1/2

3) Community :-
1. It can be only used by the group of organizations.
2. managed by the specific community
3. sharing of resources is only allowed between the organization and a specific community.

4) Hybrid :- 1. It is a combination of both private and public
2. essential and complex problems are solved by private deployment model.
3. non-essential and less complex problems are solved by public deployment model.

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Computing Paradigms

The term paradigm conveys that there is a set of practices to be followed to accomplish a task. In the domain of computing, there are many different standard practices being followed based on inventions and technological advancements. In this chapter, we look into the various computing para- digms: namely high performance computing, cluster computing, grid com- puting, cloud computing, bio-computing, mobile computing, quantum computing, optical computing, nanocomputing, and network computing. Ascomputing systems become faster and more capable, it is required to note thefeatures of modern computing in order to relate ourselves to the title of this book on cloud computing, and therefore it becomes essential to know little onvarious computing paradigms.

1.1 High-Performance Computing

In high-performance computing systems, a pool of processors (processor machines or central processing units [CPUs]) connected (networked) with other resources like memory, storage, and input and output devices, and the deployed software is enabled to run in the entire system of connected components. The processor machines can be of homogeneous or heterogeneous type. The legacy meaning of high-performance computing (HPC) is the supercomputers; however, it is not true in present-day computing scenarios. Therefore, HPC can also be attributed to mean the other computing paradigms that are discussed in the forthcoming sections, as it is a common name for all these computing systems.

Thus, examples of HPC include a small cluster of desktop computers or personal computers (PCs) to the fastest supercomputers. HPC systems are normally found in those applications where it is required to use or solve scientific problems. Most of the time, the challenge in working with these kinds of problems is to perform suitable simulation study, and this can be accomplished by HPC without any difficulty. Scientific examples such as protein folding in molecular biology and studies on developing models and applications based on nuclear fusion are worth noting as potential applications for HPC.

1.2 Parallel Computing

Parallel computing is also one of the facets of HPC. Here, a set of proces- sors work cooperatively to solve a computational problem. These processor machines or CPUs are mostly of homogeneous type. Therefore, this definition is *the same* as that of HPC and is broad enough to include supercomputers that have hundreds or thousands of processors interconnected with other resources. One can distinguish between *conventional* (also known as serial or sequential or Von Neumann) computers and parallel computers in the way the applications are executed.

In serial or sequential computers, the following apply:

- It runs on a single computer/processor machine having a single CPU.
- A problem is broken down into a discrete series of instructions.
- Instructions are executed one after another.

In parallel computing, since there is simultaneous use of multiple processor machines, the following apply:

- It is run using multiple processors (multiple CPUs).
- A problem is broken down into discrete parts that can be solved concurrently.
- Each part is further broken down into a series of instructions.
- Instructions from each part are executed simultaneously on different processors.
- An overall control/coordination mechanism is employed.

1.3 Distributed Computing

Distributed computing is also a computing system that consists of multiple computers or processor machines connected through a network, which can be homogeneous or heterogeneous, but run as a single system. The connectivity can be such that the CPUs in a distributed system can be physically close together and connected by a local network, or they can be geographically distant and connected by a wide area network. The heterogeneity in a distributed system supports any number of possible configurations in the processor machines, such as mainframes, PCs, workstations, and minicomputers. The goal of distributed computing is to make such a network work as a single computer.

Distributed computing systems are advantageous over centralized systems, because there is a support for the following characteristic features:

1. Scalability: It is the ability of the system to be easily expanded by adding more machines as needed, and vice versa, without affecting the existing setup.
2. Redundancy or replication: Here, several machines can provide the same services, so that even if one is unavailable (or failed), work does not stop because other similar computing supports will be available.

1.4 Cluster Computing

A cluster computing system consists of a set of the same or similar type of processor machines connected using a dedicated network infrastructure. All processor machines share resources such as a common home directory and have a software such as a message passing interface (MPI) implementation installed to allow programs to be run across all nodes simultaneously. This is

also a kind of HPC category. The individual computers in a cluster can be referred to as *nodes*. The reason to realize a cluster as HPC is due to the fact that the individual nodes can work together to solve a problem larger than any computer can easily solve. And, the nodes need to communicate with one another in order to work cooperatively and meaningfully together to solve the problem in hand.

If we have processor machines of heterogeneous types in a cluster, this kind of clusters become a subtype and still mostly are in the experimental or research stage.

1.1 Grid Computing

The computing resources in most of the organizations are underutilized but are necessary for certain operations. The idea of grid computing is to make use of such nonutilized computing power by the needy organizations, and thereby the return on investment (ROI) on computing investments can be increased.

Thus, grid computing is a network of computing or processor machines managed with a kind of software such as middleware, in order to access and use the resources remotely. The managing activity of grid resources through the middleware is called *grid services*. Grid services provide access control, security, access to data including digital libraries and databases, and access to large-scale interactive and long-term storage facilities.

TABLE 1.1

Electrical Power Grid and Grid Computing

Electrical Power Grid	Grid Computing
Never worry about where the electricity that we are using comes from; that is, whether it is from coal in Australia, from wind power in the United States, or from a nuclear plant in France, one can simply plug the electrical appliance into the wall-mounted socket and it will get the electrical power that we need to operate the appliance.	*Never worry* about where the computer power that we are using comes from; that is, whether it is from a supercomputer in Germany, a computer farm in India, or a laptop in New Zealand, one can simply plug in the computer and the Internet and it will get the application execution done.
The infrastructure that makes this possible is called *the power grid*. It links together many different kinds of power plants with our home, through transmission stations, power stations, transformers, power lines, and so forth.	*The infrastructure* that makes this possible is called *the computing grid*. It links together computing resources, such as PCs, workstations, servers, and storage elements, and provides the mechanism needed to access them via the Internet.
The power grid is *pervasive*: electricity is available essentially everywhere, and one can simply access it through a standard wall-	The grid is also *pervasive* in the sense that the remote computing resources would be accessible from different platforms, including laptops and mobile phones, and one can simply access the grid

mounted socket.	computing power through the web browser.
The power grid is a *utility*: we ask for electricity and we get it. We also pay forwhat we get.	The grid computing is also a *utility*: we ask for computing power or storage capacity and we get it. We also pay for what we get.

Grid computing is more popular due to the following reasons:

- Its ability to make use of unused computing power, and thus, it is a cost-effective solution (reducing investments, only recurring costs)
- As a way to solve problems in line with any HPC-based application
- Enables heterogeneous resources of computers to work cooperatively and collaboratively to solve a scientific problem

Researchers associate the term *grid* to the way electricity is distributed in municipal areas for the common man. In this context, the difference between electrical power grid and grid computing is worth noting (Table 1.1).

1.5 Cloud Computing

The computing trend moved toward cloud from the concept of grid computing, particularly when large computing resources are required to solve a single problem, using the ideas of computing power as a *utility* and other allied concepts. However, the potential difference between grid and cloud is that grid computing supports leveraging several computers in parallel to solve a particular application, while cloud computing supports leveraging multiple resources, including computing resources, to deliver a unified *service* to the end user.

In cloud computing, the IT and business resources, such as servers, storage, network, applications, and processes, can be dynamically provisioned to the user needs and workload. In addition, while a cloud can provi-sion and support a grid, a cloud can also support nongrid environments, such as a three-tier web architecture running on traditional or Web 2.0 applications.

We will be looking at the details of cloud computing in different chapters of this book.

1.6 Biocomputing

Biocomputing systems use the concepts of biologically derived or simulated molecules (or models) that perform computational processes in order to solve a problem. The biologically derived models aid in structuring the computer programs that become part of the application.

Biocomputing provides the theoretical background and practical toolsfor

scientists to explore proteins and DNA. DNA and proteins are nature's building blocks, but these building blocks are not exactly used as *bricks*; the function of the final molecule rather strongly depends on the *order* of these blocks. Thus, the biocomputing scientist works on inventing the *order* suitable for various applications mimicking biology. Biocomputing shall, therefore, lead to a better understanding of life and the molecular causes of certain diseases.

1.1 Mobile Computing

In mobile computing, the processing (or computing) elements are small (i.e., handheld devices) and the communication between various resources is taking place using wireless media.

Mobile communication for voice applications (e.g., cellular phone) is widely established throughout the world and witnesses a very rapid growth in all its dimensions including the increase in the number of subscribers of various cellular networks. An extension of this technology is the ability to send and receive data across various cellular networks using small devices such as smartphones. There can be numerous applications based on this technology; for example, video call or conferencing is one of the important applications that people prefer to use in place of existing voice (only) communications on mobile phones.

Mobile computing–based applications are becoming very important and rapidly evolving with various technological advancements as it allows users to transmit data from remote locations to other remote orfixed locations.

1.2 Quantum Computing

Manufacturers of computing systems say that there is a limit for cramming more and more transistors into smaller and smaller spaces of integrated circuits (ICs) and thereby doubling the processing power about every 18 months. This problem will have to be overcome by a new *quantum computing*–based solution, wherein the dependence is on quantum information, the rules that govern the subatomic world. Quantum computers are millions of times faster than even our most powerful supercomputers today. Since quantum computing works differently on the most fundamental level than the current technology, and although there are working prototypes, these systems have not so far proved to be alternatives to today's silicon-based machines.

1.3 Optical Computing

Optical computing system uses the photons in visible light or infraredbeams, rather than electric current, to perform digital computations. An elec-tric current flows at only about 10% of the speed of light. This limits the rateat which data can be exchanged over long distances and is one of the factors that led to the evolution of optical fiber. By applying some of the advantages of visible and/or IR networks at the device and component scale, a computer can be developed that can perform operations 10 or more times faster than

aconventional electronic computer.

1.4 Nanocomputing

Nanocomputing refers to computing systems that are constructed from nanoscale components. The silicon transistors in traditional computers may be replaced by transistors based on carbon nanotubes.

The successful realization of nanocomputers relates to the scale and integration of these nanotubes or components. The issues of scale relate to the dimensions of the components; they are, at most, a few nanometers in at least two dimensions. The issues of integration of the components are twofold: first, the manufacture of complex arbitrary patterns may be economically infeasible, and second, nanocomputers may include massive quantities of devices. Researchers are working on all these issues to bring nanocomputing a reality.

1.5 Network Computing

Network computing is a way of designing systems to take advantage of the latest technology and maximize its positive impact on business solutions and their ability to serve their customers using a strong underlying network of computing resources. In any network computing solution, the client component of a networked architecture or application will be with the customer or client or end user, and in modern days, they provide an essential set of functionality necessary to support the appropriate client functions at minimum cost and maximum simplicity. Unlike conventional PCs, they do not need to be individually configured and maintained according to their intended use. The other end of the client component in the network architecture will be a typical *server* environment to *push* the services of the application to the client end.

Almost all the computing paradigms that were discussed earlier are of this nature. Even in the future, if any one invents a totally new computing paradigm, it would be based on a networked architecture, without which it is impossible to realize the benefits for any end user.

1.1 Summary

We are into a post-PC era, in which a greater number and a variety of computers and computing paradigms with different sizes and functions might be used everywhere and with every human being; so, the purpose of this chapter is to illustrate briefly the ideas of all these computing domains, as most of these are ubiquitous and pervasive in its access and working environment.

2

Cloud Computing Fundamentals

Modern computing with our laptop or desktop or even with tablets/smart- phones using the Internet to access the data and details that we want, which are located/stored at remote places/computers, through the faces of appli- cations like Facebook, e-mail, and YouTube, brings the actual power of information that we need instantaneously within no time. Even if millionsof users get connected in this manner, from anywhere in the world, these applications do serve what these users–customers want. This phenomenon of supply of information or any other data and details to all the needy cus- tomers, as and when it is asked, is the conceptual understanding and work-ing of what is known as cloud computing. This chapter is devoted to give basic understanding on cloud computing.

2.1 Motivation for Cloud Computing

Let us review the scenario of computing prior to the announcement and availability of cloud computing: The users who are in need of computing are expected to invest money on computing resources such as hardware, software, networking, and storage; this investment naturally costs a bulk currency to the users as they have to buy these computing resources, keep these in their premises, and maintain and make it operational—all these tasks would add cost. And, this is a particularly true and huge expenditure to the enterprises that require enormous computing power and resources, compared with classical academics and individuals.

On the other hand, it is easy and handy to get the required computing power and resources from some provider (or supplier) as and when it is needed and pay only for that usage. This would cost only a reasonable invest- ment or spending, compared to the huge investment when buying the entire computing infrastructure. This phenomenon can be viewed as *capital expen- diture* versus *operational expenditure*. As one can easily assess the huge lump sum required for capital expenditure (whole investment and maintenance forcomputing infrastructure) and compare it with the moderate or smaller lump sum required for the hiring or getting the computing infrastructure only to the tune of required time, and rest of the time free from that. Therefore, cloud computing is a mechanism of *bringing–hiring or getting the services of the com- puting power or infrastructure* to an organizational or individual level to the extent required and paying only for the consumed services.

One can compare this situation with the usage of electricity (its services) from its producer-cum-distributor (in India, it is the state-/government-owned electricity boards that give electricity supply to all residences and organiza- tions) to houses or organizations; here, we do not generate electricity (compa-rable with electricity production–related tasks); rather, we use it only to tuneup our requirements in our premises, such as for our lighting and usage ofother electrical appliances, and pay as per the electricity meter

reading value.Therefore, cloud computing is needed in getting the services of comput- ing resources. Thus, one can say as a one-line answer to the need for cloudcomputing that it eliminates a large computing investment without compro-mising the use of computing at the user level at an operational cost. Cloudcomputing is very economical and saves a lot of money. A blind benefit ofthis computing is that even if we lose our laptop or due to some crisis ourpersonal computer—and the desktop system—gets damaged, still our dataand files will stay safe and secured as these are not in our local machine (but remotely located at the provider's place—machine).

In addition, one can think to add security while accessing these remote computing resources as depicted in Figure 2.1.

Figure 2.1 shows several cloud computing applications. The *cloud* representsthe Internet-based computing resources, and the accessibility is through some

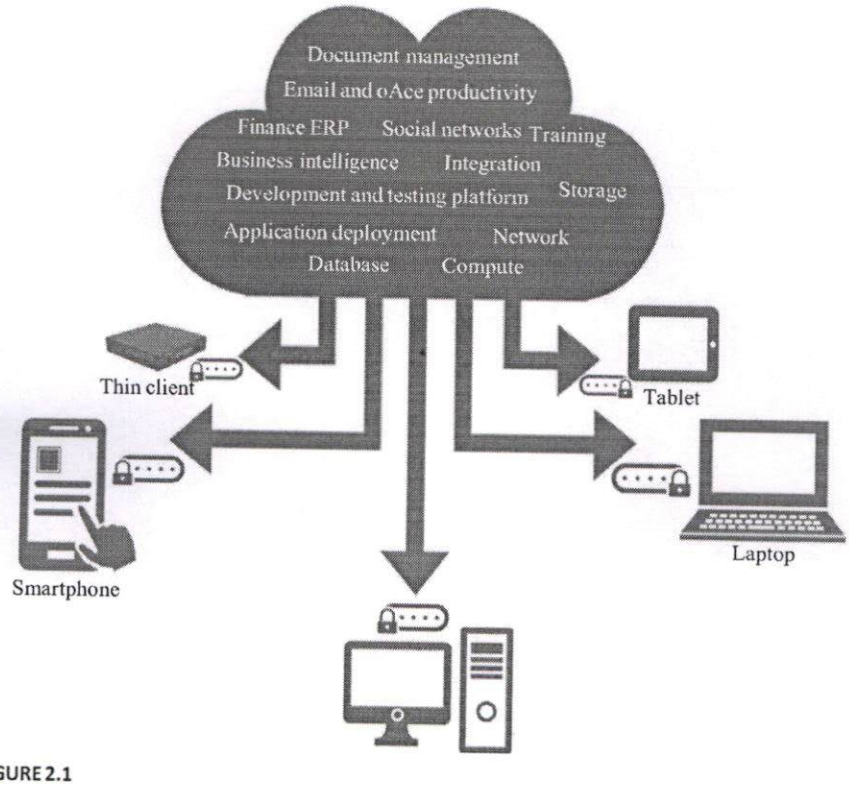


FIGURE 2.1
Cloud computing.

secure support of connectivity. It is a computing solution growing in popularity, especially among individuals and small- and medium-sized companies (SMEs). In the cloud computing model, an organization's core computer power resides offsite and is essentially subscribed to rather than owned.

Thus, cloud computing comes into focus and much needed only when we think about what computing resources and information technology (IT) solutions are required. This need caters to a way to increase capacity or add capabilities on the fly without investing in new infrastructure, training new personnel, or licensing new software. Cloud computing encompasses the subscription-based or pay-per-use service model of offering computing to end users or customers over the Internet and thereby extending the IT's existing capabilities.

2.1.1 The Need for Cloud Computing

The main reasons for the need and use of cloud computing are convenience andreliability. In the past, if we wanted to bring a file, we would have to save it to aUniversal Serial Bus (USB) flash drive, external hard drive, or compact disc (CD)and bring that device to a different place. Instead, saving a file to the cloud(e.g., use of cloud application Dropbox) ensures that we will be able to access itwith any computer that has an Internet connection. The cloud also makes it mucheasier to share a file with friends, making it possible to collaborate over the web. While using the cloud, losing our data/file is much less likely. However, just like anything online, there is always a risk that someone may try to gainaccess to our personal data, and therefore, it is important to choose an accesscontrol with a strong password and pay attention to any privacy settings for
the cloud service that we are using.

2.1 Defining Cloud Computing

In the simplest terms, cloud computing means storing and accessing data and programs over the Internet from a remote location or computer instead of our computer's hard drive. This so called *remote location* has several properties such as scalability, elasticity etc., which is significantly different from a simple remote machine. The cloud is just a metaphor for the Internet. When we store data on or run a program from the local computer's hard drive, that is called local storage and computing. For it to be considered *cloud computing*, we need to access our data or programs over the Internet. The endresult is the same; however, with an online connection, cloud computing canbe done anywhere, anytime, and by any device.

2.1.1 NIST Definition of Cloud Computing

The formal definition of cloud computing comes from the National Institute of Standards and Technology (NIST): "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models [1]. It means that the computing resource or infrastructure—be it server hardware,storage, network, or application software—all available from the cloud vendoror provider's site/premises, can be accessible over the Internet from any remotelocation and by any local computing device. In addition, the usage or accessibil-ity is to cost only to the level of usage to the customers based on their needs and demands, also known as the *pay-as-you-go* or *pay-as-per-use* model. If the needis more, more quantum computing resources are made available (provisioningwith elasticity) by the provider. Minimal management effort implies that at thecustomer's side, the maintenance of computing systems is very minimal as theywill have to look at these tasks only for their local computing devices used foraccessing cloud-based resources, not for those computing resources managed atthe provider's side. Details of five essential characteristics, three service models,

and four deployment models are provided in the 5-4-3 principles in Section 2.3.Many vendors, pundits, and experts refer to NIST, and both the InternationalStandards Organization (ISO) and the Institute of Electrical and Electronics Engineers (IEEE) back the NIST definition.

Now, let us try to define and understand cloud computing from two other perspectives—as a service and a platform—in the following sections.

2.1.2 Cloud Computing Is a Service

The simplest thing that any computer does is allow us to store and retrieve information. We can store our family photographs, our favorite songs, or even save movies on it, which is also the most basic service offered by cloud computing. Let us look at the example of a popular application called *Flickr* to illustrate the meaning of this section.

While Flickr started with an emphasis on sharing photos and images, it has emerged as a great place to store those images. In many ways, it is supe-rior to storing the images on your computer:

1. First, Flickr allows us to easily access our images no matter where we are or what type of device we are using. While we might uploadthe photos of our vacation from our home computer, later, we can easily access them from our laptop at the office.
2. Second, Flickr lets us share the images. There is no need to burn them to a CD or save them on a flash drive. We can just send someone our Flickr address to share these photos or images.
3. Third, Flickr provides data security. By uploading the images to Flickr, we are providing ourselves with data security by creating a backup on the web. And, while it is always best to keep a local copy—either on a computer, a CD, or a flash drive—the truth is that we arefar more likely to lose the images that we store locally than Flickr is of losing our images.

2.1.3 Cloud Computing Is a Platform

The World Wide Web (WWW) can be considered as the operating system for all our Internet-based applications. However, one has to understand thatwe will always need a local operating system in our computer to access web-based applications.

The basic meaning of the term *platform* is that it is the support on which applications run or give results to the users. For example, Microsoft Windows is a platform. But, a platform does not have to be an operating system. Java isa platform even though it is not an operating system.

Through cloud computing, the web is becoming a platform. With trends (applications) such as Office 2.0, more and more applications that were originally available on desktop computers are now being converted into web–cloud applications. Word processors like Buzzword and office suites like Google Docs are now available in the cloud as their desktop counter-parts. All these kinds of trends in providing applications via the cloud are turning cloud computing into a platform or to act as a platform.

2.1 5-4-3 Principles of Cloud computing

The 5-4-3 principles put forth by NIST describe (a) the five essential characteristic features that promote cloud computing, (b) the four deployment models that are used to narrate the cloud computing opportunities for customers while looking at architectural models, and (c) the three important and basic service offering models of cloud computing.

2.1.1 Five Essential Characteristics

Cloud computing has five essential characteristics, which are shown inFigure 2.2. Readers can note the word *essential*, which means that if any of these characteristics is missing, then it is not cloud computing:

1. *On-demand self-service*: A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction witheach service's provider.
2. *Broad network access*: Capabilities are available over the network and accessed through standard mechanisms that promote use by hetero-geneous thin or thick client platforms (e.g., mobile phones, laptops, and personal digital assistants [PDAs]).

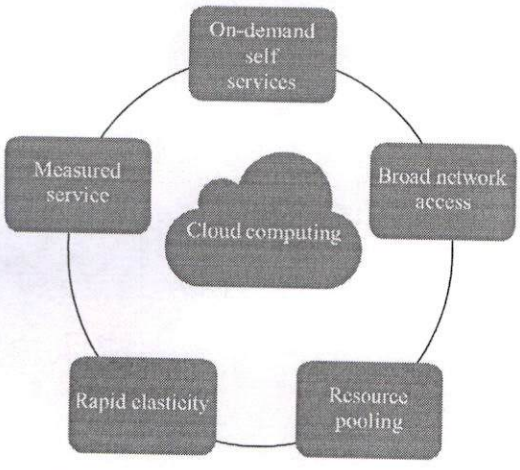


FIGURE 2.2
The essential characteristics of cloud computing.

1. **Elastic resource pooling**: The provider's computing resources are pooled to serve multiple consumers using a multitenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify the location at a higher level of abstraction (e.g., country, state, or data center). Examples of resources include storage, processing, memory, and network bandwidth.
2. **Rapid elasticity**: Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.
3. **Measured service**: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of

abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

2.1.4 Four Cloud Deployment Models

Deployment models describe the ways with which the cloud services can be deployed or made available to its customers, depending on the organizational structure and the provisioning location. One can understand it in this manner too: cloud (Internet)-based computing resources—that is, the locations where data and services are acquired and provisioned to its customers— can take various forms. Four deployment models are usually distinguished, namely, public, private, community, and hybrid cloud service usage:

1. **Private cloud**: The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.
2. **Public cloud**: The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
3. **Community cloud**: The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on premise or off premise.
4. **Hybrid cloud**: The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application porta- bility (e.g., cloud bursting for load balancing between clouds).

2.1.5 Three Service Offering Models

The three kinds of services with which the cloud-based computing resources are available to end customers are as follows: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). It is also known as the service--platform–infrastructure (SPI) model of the cloud and is shown in Figure 2.3. SaaS is a software distribution model in which applications (software, which is one of the most important computing resources) are hosted by a vendor or service provider and made available to customers over a network, typically the Internet. PaaS is a paradigm for delivering operating systems and associated services (e.g., computer aided software engineering [CASE] tools, integrated development environments [IDEs] for developing software solutions) over the Internet without downloads or installation. IaaS involves outsourcing the equipment used to support operations, including storage, hardware, servers, and networking components.

1. **Cloud SaaS**: The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure, includ- ing

network, servers, operating systems, storage, and even individ- ual application capabilities, with the possible exception of limited user-specific application configuration settings. The applications are accessible from various client devices through either a thin client

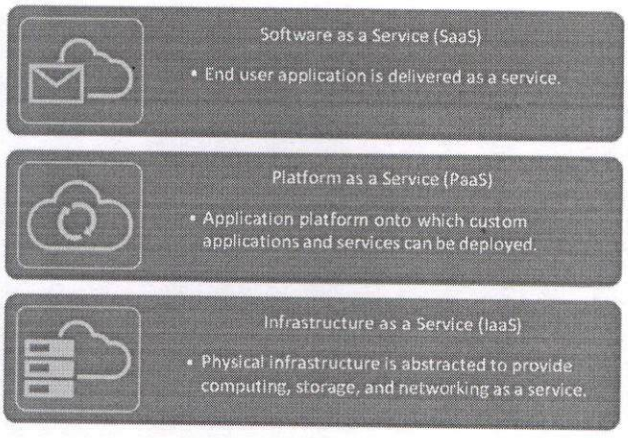


FIGURE 2.3
SPI—service offering model of the cloud.

interface, such as a web browser (e.g., web-based e-mail), or a program interface. The consumer does not manage or control the underlying cloud infrastructure. Typical applications offered as a service include customer relationship management (CRM), business intelligence analytics, and online accounting software.

2. **Cloud PaaS**: The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applica-tions created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure but has control over the deployed applications and possibly configuration settings for the application-hosting environment. In other words, it is a packaged and ready-to-run development or operating framework. The PaaS vendor provides the networks, servers, and storage and manages the levels of scalability and maintenance. The client typically pays for services used. Examples of PaaS providers include Google App Engine and Microsoft Azure Services.
3. **Cloud IaaS**: The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources on a pay-per-use basis where he or she is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over the operating systems, storage, and deployed applications and possibly limited control of select networking components (e.g., host firewalls). The service provider owns the equipment and is responsible for housing, cooling operation, and maintenance. Amazon Web Services (AWS) is a popular example of a large IaaS provider.

The major difference between PaaS and IaaS is the amount of control that users have. In essence, PaaS allows vendors to manage everything, while IaaS requires more management from the customer side. Generally speak- ing,

organizations that already have a software package or application for a specific purpose and want to install and run it in the cloud should opt to use IaaS instead of PaaS.

3

Cloud Computing Architectureand Management

Cloud computing is an emerging technology that has become one of the most popular computing technologies. Each and every technology has cer- tain concepts that form the basis for its working. Similarly, there are sev- eral aspects of a technology that needs to be looked upon before delving deeper. Thus, there are some basic issues in cloud computing that need tobe discussed before going into a detailed discussion about the cloud. This chapter firstly describes the cloud architecture. Cloud architecture consists of a hierarchical set of components that collectively describe the way the cloud works. The next section explains about the cloud anatomy, followed by network connectivity in the cloud and then the fine details about managing a cloud application. Finally, an overview on migrating applications to the cloud is discussed. Some of the topics that are discussed in this chapter are elaborated in upcoming chapters.

3.1 Introduction

Cloud computing is similar to other technologies in a way that it alsohas several basic concepts that one should learn before knowing its core concepts. There are several processes and components of cloud computing that need to be discussed. One of the topics of such prime importance is architecture. Architecture is the hierarchical view of describinga technology. This usually includes the components over which the existing technology is built and the components that are dependent onthe technology. Another topic that is related to architecture is anatomy. Anatomy describes the core structure of the cloud. Once the structure of the cloud is clear, the network connections in the cloud and the details about the cloud application need to be known. This is important as the cloud is a completely Internet-dependent technology. Similarly, cloud management discusses the important management issues and ways in which the current cloud scenario is managed. It describes the way an application and infrastructure in the cloud are managed. Management is important

because of the quality of service (QoS) factors that are involvedin the cloud. These QoS factors form the basis for cloud computing. Allthe services are given based on these QoS factors. Similarly, application migration to the cloud also plays a very important role. Not all applica- tions can be directly deployed to the cloud. An application needs to be properly migrated to the cloud to be considered a proper cloud applica-tion that will have all the properties of the cloud.

3.2 Cloud Architecture

Any technological model consists of an architecture based on which the model functions, which is a hierarchical view of describing the technology. The cloud also has an architecture that describes its working mechanism. It includes the dependencies on which it works and the components that work over it. The cloud is a recent technology that is completely dependent on the Internet for its functioning. Figure 3.1 depicts the architecture. The cloud architecture can be divided into four layers based on the access of the cloud by the user. They are as follows.

3.2.1 Layer 1 (User/Client Layer)

This layer is the lowest layer in the cloud architecture. All the users or client belong to this layer. This is the place where the client/user initiates the

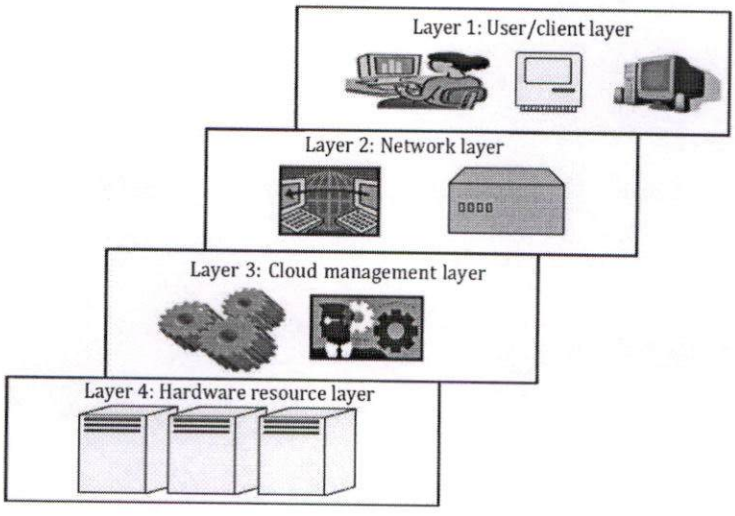


FIGURE 3.1
Cloud architecture

connection to the cloud. The client can be any device such as a thin client, thick client, or mobile or any handheld device that would support basic functionalities to access a web application. The thin client here refers to a device that is completely dependent on some other system for its complete functionality. In simple terms, they have very low processing capability. Similarly, thick clients are general computers that have adequate processing capability. They have sufficient capability for independent work. Usually, a cloud application can be accessed in the same way as a web application. But internally, the properties of cloud applications are significantly different. Thus, this layer consists of client devices.

3.2.2 Layer 2 (Network Layer)

This layer allows the users to connect to the cloud. The whole cloud infrastructure is dependent on this connection where the services are offered to the customers. This is primarily the Internet in the case of a public cloud. The public cloud usually exists in a specific location and the user would notknow the location as it is abstract. And, the public cloud can be accessed all over the world. In the case of a private cloud, the connectivity may be pro- vided by a local area network (LAN). Even in this case, the cloud completelydepends on the network that is used. Usually, when accessing the public or private cloud, the users require minimum bandwidth, which is sometimes defined by the cloud providers. This layer does not come under the purviewof service-level agreements (SLAs), that is, SLAs do not take into account theInternet connection between the user and cloud for quality of service (QoS).

3.2.3 Layer 3 (Cloud Management Layer)

This layer consists of softwares that are used in managing the cloud. The softwares can be a cloud operating system (OS), a software that acts as an interface between the data center (actual resources) and the user, or a management soft- ware that allows managing resources. These softwares usually allow resource management (scheduling, provisioning, etc.), optimization (server consolida- tion, storage workload consolidation), and internal cloud governance. This layer comes under the purview of SLAs, that is, the operations taking place in this layer would affect the SLAs that are being decided upon between the users and the service providers. Any delay in processing or any discrepancy in ser- vice provisioning may lead to an SLA violation. As per rules, any SLA violationwould result in a penalty to be given by the service provider. These SLAs arefor both private and public clouds Popular service providers are Amazon WebServices (AWS) and Microsoft Azure for public cloud. Similarly, OpenStackand Eucalyptus allow private cloud creation, deployment, and management.

3.2.4 Layer 4 (Hardware Resource Layer)

Layer 4 consists of provisions for actual hardware resources. Usually, in the case of a public cloud, a data center is used in the back end. Similarly, in a private cloud, it can be a data center, which is a huge collection of hardware resources interconnected to each other that is present in a specific location ora high configuration system. This layer comes under the purview of SLAs. This is the most important layer that governs the SLAs. This layer affects the SLAs most in the case of data centers. Whenever a user accesses the cloud, it should be available to the users as quickly as possible and should be within

the time that is defined by the SLAs. As mentioned, if there is any discrepancy in provisioning the resources or application, the service provider has to pay the penalty. Hence, the data center consists of a high-speed network connection and a highly efficient algorithm to transfer the data from the data center to the manager. There can be a number of data centers for a cloud, and similarly, a number of clouds can share a data center.

Thus, this is the architecture of a cloud. The layering is strict, and for any cloud application, this is followed. There can be a little loose isolation between layer 3 and layer 4 depending on the way the cloud is deployed.

3.3 Anatomy of the Cloud

Cloud anatomy can be simply defined as the structure of the cloud. Cloud anatomy cannot be considered the same as cloud architecture. It may not include any dependency on which or over which the technology works,

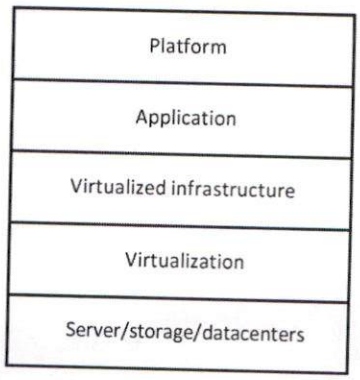


FIGURE 3.2
Cloud structure.

whereas architecture wholly defines and describes the technology over which it is working. Architecture is a hierarchical structural view that defines the technology as well as the technology over which it is dependent or/and the technology that are dependent on it. Thus, anatomy can be con- sidered as a part of architecture. The basic structure of the cloud is describedin Figure 3.2, which can be elaborated, and minute structural details can be given. Figure 3.2 depicts the most standard anatomy that is the base for the cloud. It depends on the person to choose the depth of description of the cloud. A different view of anatomy is given by Refs. [1,2].

There are basically five components of the cloud:

1. **Application**: The upper layer is the application layer. In this layer, any applications are executed.
2. **Platform**: This component consists of platforms that are responsible for the execution of the application. This platform is between the infrastructure and the application.
3. **Infrastructure**: The infrastructure consists of resources over which the other components work. This provides computational capability to the user.

4. **Virtualization**: Virtualization is the process of making logical components of resources over the existing physical resources. The logical components are isolated and independent, which form the infrastructure.
5. **Physical hardware**: The physical hardware is provided by server and storage units.

These components are the basis and are described in detail in further chapters.

3.4 Network Connectivity in Cloud Computing

Cloud computing is a technique of resource sharing where servers, storage, and other computing infrastructure in multiple locations are connected by networks. In the cloud, when an application is submitted for its execution, needy and suitable resources are allocated from this collection of resources; as these resources are connected via the Internet, the users get their required results. For many cloud computing applications, network performance will be the key issue to cloud computing performance. Since cloud computing has various deployment options, we now consider the important aspects related to the cloud deployment models and their accessibility from the viewpoint of network connectivity.

3.4.1 Public Cloud Access Networking

In this option, the connectivity is often through the Internet, though some cloud providers may be able to support virtual private networks (VPNs) for customers. Accessing public cloud services will always create issues related to security, which in turn is related to performance. One of the possible approaches toward the support of security is to promote connectivity through encrypted tunnels, so that the information may be sent via secure pipes on the Internet. This procedure will be an overhead in the connectivity, and using it will certainly increase delay and may impact performance.

If we want to reduce the delay without compromising security, then we have to select a suitable routing method such as the one reducing the delay by minimizing transit *hops* in the end-to-end connectivity between the cloud provider and cloud consumer. Since the end-to-end connectivity support is via the Internet, which is a complex federation of interconnected providers (known as Internet service providers [ISPs]), one has to look at the options of selecting the path.

3.4.2 Private Cloud Access Networking

In the private cloud deployment model, since the cloud is part of an organizational network, the technology and approaches are local to the in-house network structure. This may include an Internet VPN or VPN service from a network operator. If the application access was properly done with an organizational network—connectivity in a *precloud* configuration—transition to private cloud computing will not affect the access performance.

3.4.3 Intracloud Networking for Public Cloud Services

Another network connectivity consideration in cloud computing is intra-

cloud networking for public cloud services. Here, the resources of the cloud provider and thus the cloud service to the customer are based on the resources that are geographically apart from each other but still connected via the Internet. Public cloud computing networks are internal to the ser- vice provider and thus not visible to the user/customer; however, the secu- rity aspects of connectivity and the access mechanisms of the resources are important. Another issue to look for is the QoS in the connected resources worldwide. Most of the performance issues and violations from these are addressed in the SLAs commercially.

3.4.4 Private Intracloud Networking

The most complicated issue for networking and connectivity in cloud com- puting is private intracloud networking. What makes this particular issue so complex is that it depends on how much intracloud connectivity is associ- ated with the applications being executed in this environment. Private intra- cloud networking is usually supported over connectivity between the major data center sites owned by the company. At a minimum, all cloud computing implementations will rely on intracloud networking to link users with the resource to which their application was assigned. Once the resource link- age is made, the extent to which intracloud networking is used depends on whether the application is componentized based on *service-oriented architec- ture (SOA)* or not, among multiple systems. If the principle of SOA is fol- lowed, then traffic may move between components of the application, as wellas between the application and the user. The performance of those connec- tions will then impact cloud computing performance overall. Here too, the impact of cloud computing performance is the differences that exist between the current application and the network relationships with the application.

There are reasons to consider the networks and connectivity in cloud computing with newer approaches as globalization and changing network requirements, especially those related to increased Internet usage, are demanding more flexibility in the network architectures of today's enter- prises. How are these related to us? The answers are discussed later.

3.4.5 New Facets in Private Networks

Conventional private networks have been architected for on-premise applica- tions and maximum Internet security. Typically, applications such as e-mail, file sharing, and *enterprise resource planning* (ERP) systems are delivered to on-premise-based servers at each corporate data center. Increasingly today, software vendors are offering Software as a Service (SaaS) as an alternative for their software support to the corporate offices, which brings more chal- lenges in the access and usage mechanisms of software from data center servers and in the connectivity of network architectures. The traditional net- work architecture for these global enterprises was not designed to optimize performance for cloud applications, now that many applications including

mission-critical applications are transitioning (moving) from on-premise based to cloud based, wherein the network availability becomes as mission critical as electricity: the business cannot function if it cannot access applica- tions such as ERP and e-mail.

3.4.6 Path for Internet Traffic

The traditional Internet traffic through a limited set of Internet gateways poses performance and availability issues for end users who are usingcloud-based applications. It can be improved if a more widely distributed Internet gateway infrastructure and connectivity are being supported for accessing applications, as they will provide lower-latency access to their cloud applications. As the volume of traffic to cloud applications grows, the percentage of the legacy network's capacity in terms of traffic to regional gateways increases. Applications such as video conferencing would hog more bandwidth while mission-critical applications such as ERP will con- sume less bandwidth, and hence, one has to plan a correct connectivity and path between providers and consumers.

3.5 Applications on the Cloud

The power of a computer is realized through the applications. There are several types of applications. The first type of applications that was developed and used was a stand-alone application. A stand-alone application is developed to be run on a single system that does not use network for its functioning. These stand-alone systems use only the machine in which they are installed. The functioning of these kinds of systems is totally dependent on the resources or features available within the system. These systems do not need the data or processing power of other systems; they are self-sustaining. But as the time passed, the requirements of the users changed and certain applications were required, which could be accessed by other users away from the systems. This led to the inception of web application.

The web applications were different from the stand-alone applications in many aspects. The main difference was the client server architecture that was followed by the web application. Unlike stand-alone applica- tions, these systems were totally dependent on the network for its work- ing. Here, there are basically two components, called as the client and the server. The server is a high-end machine that consists of the web appli- cation installed. This web application is accessed from other client sys-tems. The client can reside anywhere in the network. It can access the web application through the Internet. This type of application was very useful, and this is extensively used from its inception and now has become an

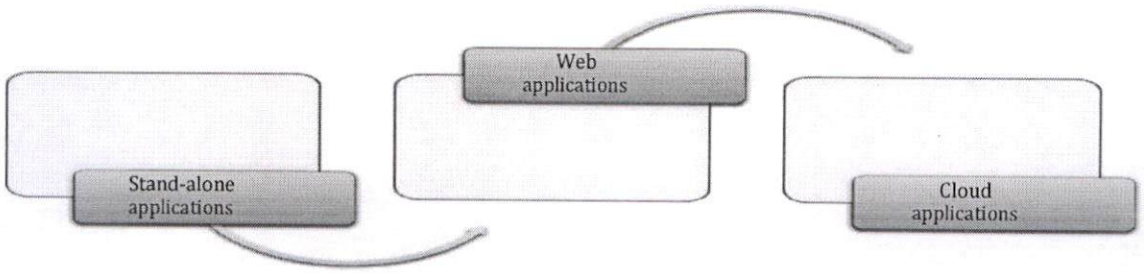


FIGURE 3.3
Computer application evolution.

important part of day-to-day life. Though this application is much used, there are shortcomings as discussed in the following:

- The web application is not elastic and cannot handle very heavy loads, that is, it cannot serve highly varying loads.
- The web application is not multitenant.
- The web application does not provide a quantitative measurement of the services that are given to the users, though they can monitor the user.
- The web applications are usually in one particular platform.
- The web applications are not provided on a pay-as-you-go basis; thus, a particular service is given to the user for permanent or trial use and usually the timings of user access cannot be monitored.
- Due to its nonelastic nature, peak load transactions cannot be handled.

Primarily to solve the previously mentioned problem, the cloud applications were developed. Figure 3.3 depicts the improvements in the applications.

The cloud as mentioned can be classified into three broad access or service models, Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Cloud application in general refers to a SaaS application.

A cloud application is different from other applications; they have unique features. A cloud application usually can be accessed as a web application but its properties differ. According to NIST [3], the features that make cloud applications unique are described in the following (Figure 3.4 depicts the features of a cloud application):

1. **Multitenancy**: Multitenancy is one of the important properties of cloud that make it different from other types of application in which the software can be shared by different users with full independence. Here, independence refers to logical independence.

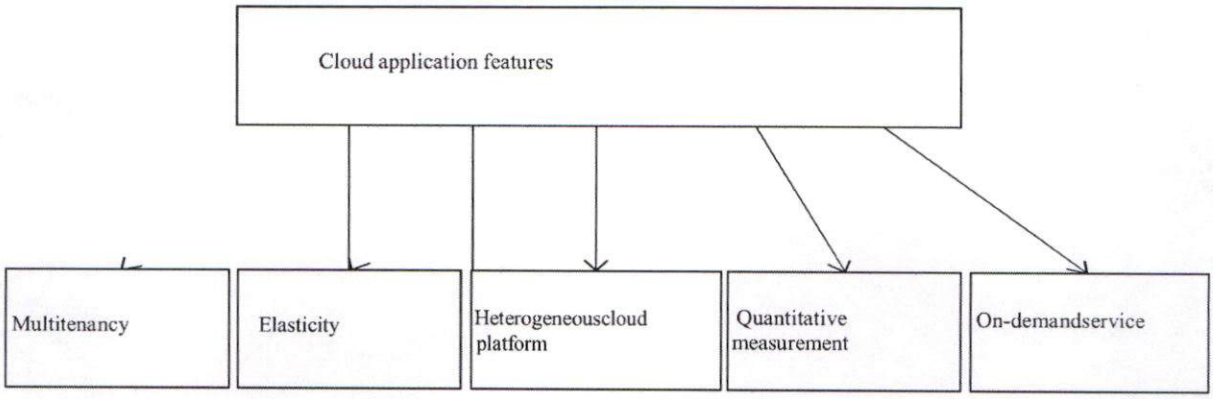


FIGURE 3.4
Features of cloud.

Each user will have a separate application instance and the changes in one application would not affect the other. Physically, the software is shared and is not independent. The degree of physical isolation is very less. The logical independence is what is guaranteed. There are no restrictions in the number of applications being shared. The difficulty in providing logical isolation depends on the physical isolation to a certain extent. If an application is physically too close, then it becomes difficult to provide multitenancy. Web application and cloud application are similar as the users use the same way to access both. Figure 3.5 depicts a multitenant application where several users share the same application.

2. **Elasticity**: Elasticity is also a unique property that enables the cloud to serve better. According to Herbst et al. [4], elasticity can be defined as the degree to which a system is able to adapt to workload changes by provisioning and deprovisioning resources in an autonomic manner such that at each point in time, the available resources match the current demand as closely as possible. Elasticity allows the cloud providers to efficiently handle the number of users, from one to

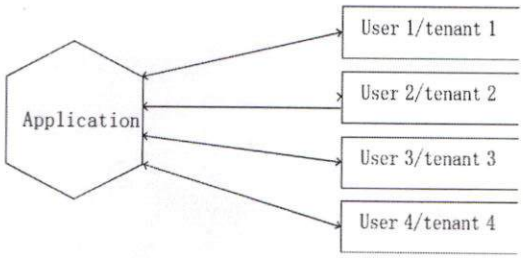


FIGURE 3.5
Multitenancy.

several hundreds of users at a time. In addition to this, it supports the rapid fluctuation of loads, that is, the increase or decrease in the number of users and their usage can rapidly change.

3. **Heterogeneous cloud platform**: The cloud platform supports heterogeneity, wherein any type of application can be deployed in the cloud. Because of this property, the cloud is flexible for the developers, which facilitates deployment. The applications that are usually deployed can be accessed by the users using a web browser.

4. **Quantitative measurement**: The services provided can be quantitativelymeasured. The user is usually offered services based on certain charges. Here, the application or resources are given as a utility on a pay-per-use basis. Thus, the use can be monitored and measured. Notonly the services are measureable, but also the link usage and severalother parameters that support cloud applications can be measured. This property of measuring the usage is usually not available in a web application and is a unique feature for cloud-based applications.
5. **On-demand service**: The cloud applications offer service to the user, on demand, that is, whenever the user requires it. The cloud service would allow the users to access web applications usually without any restrictions on time, duration, and type of device used.

The previously mentioned properties are some ofthe features that make cloud a unique application platform. These properties mentioned are specific to the cloud hence making it as one of the few technologies that allows application developers to suffice the user's needs seamlessly without any disruption.

3.6 Managing the Cloud

Cloud management is aimed at efficiently managing the cloud so as to maintain the QoS. It is one of the prime jobs to be considered. The whole cloud is dependent on the way it is managed. Cloud management can be divided into two parts:

1. Managing the infrastructure of the cloud
2. Managing the cloud application

3.6.1 Managing the Cloud Infrastructure

The infrastructure of the cloud is considered to be the backbone of the cloud. This component is mainly responsible for the QoS factor. If the infrastructure is not properly managed, then the whole cloud can fail and QoS would be adversely affected. The core of cloud management is resource management. Resource management involves several internal tasks such as resource scheduling, provisioning, and load balancing. These tasks are mainly managed by the cloud service provider's core software capabilities such as the cloud OS that is responsible for providing services to the cloud and that internally controls the cloud. A cloud infrastructure is a very complex system that consists of a lot of resources. These resources are usually shared by several users.

Poor resource management may lead to several inefficiencies in terms of performance, functionality, and cost. If a resource is not efficiently managed, the performance of the whole system is affected. Performance is the most important aspect of the cloud, because everything in the cloud is depen- dent on the SLAs and the SLAs can be satisfied only if performance is good. Similarly, the basic functionality of the cloud should always be provided and considered at any cost. Even if there is a small discrepancy in providing the

functionality, the whole purpose of maintaining the cloud is futile. A partially functional cloud would not satisfy the SLAs.

Lastly, the reason for which the cloud was developed was cost. The cost is a very important criterion as far as the business prospects of the cloud are concerned. On the part of the service providers, if they incur less cost for managing the cloud, then they would try to reduce the cost so as to get a strong user base. Hence, a lot of users would use the services, improving their profit margin. Similarly, if the cost of resource management is high, then definitely the cost of accessing the resources would be high and there is never a lossy business from any organization and so the service provider would not bear the cost and hence the users have to pay more. Similarly, this would prove costly for service providers as they have a high chance of losinga wide user base, leading to only a marginal growth in the industry. And, competing with its industry rivals would become a big issue. Hence, efficient management with less cost is required.

At a higher level, other than these three issues, there are few more issues that depend on resource management. These are power consumption and optimization of multiple objectives to further reduce the cost. To accomplish these tasks, there are several approaches followed, namely, consolidation of server and storage workloads. Consolidation would reduce the energy consumption and in some cases would increase the performance of the cloud. According to Margaret Rouse [5], server consolidation by definition is an approach to the efficient usage of computer server resources in order to reduce the total number of servers or server locations that an organization requires.

The previously discussed prospects are mostly suitable for IaaS. Similarly, there are different management methods that are followed for different types of service delivery models. Each of the type has its ownway of management. All the management methodologies are based on load fluctuation. Load fluctuation is the point where the workload of the system changes continuously. This is one of the important criteria andissues that should be considered for cloud applications. Load fluctuation can be divided into two types: predictable and unpredictable. Predictable load fluctuations are easy to handle. The cloud can be preconfigured for handling such kind of fluctuations. Whereas unpredictable load fluctu- ations are difficult to handle, ironically this is one of the reasons whycloud is preferred by several users.

This is as far as cloud management is concerned. Cloud governance is another topic that is closely related to cloud management. Cloud governance is different from cloud management. Governance in general is a term in the corporate world that generally involves the process of creating value to an organization by creating strategic objectives that will lead to the growth of the company and would maintain a certain level of control over the company. Similar to that, here cloud organization is involved.

There are several aspects of cloud governance out of which SLAs are one of the important aspects. SLAs are the set of rules that are defined between the user and cloud service provider that decide upon the QoS factor. If SLAs are not followed, then the defaulter has to pay the penalty. The whole cloud is governed by keeping these SLAs in mind. Cloud governance is discussed in detail in further chapters.

3.6.2 Managing the Cloud Application

Business companies are increasingly looking to move or build their corporate applications on cloud platforms to improve agility or to meet dynamic requirements that exist in the globalization of businesses and responsiveness to market demands. But, this shift or moving the applications to the cloud environment brings new complexities. Applications become more composite and complex, which requires leveraging not only capabilities like storage and database offered by the cloud providers but also third-party SaaS capabilities like e-mail and messaging. So, understanding the availability of an application requires inspecting the infrastructure, the services it consumes, and the upkeep of the application. The composite nature of cloud applications requires visibility into all the services to determine the overall availability and uptime.

Cloud application management is to address these issues and propose solutions to make it possible to have insight into the application that runs in the cloud, as well as implement or enforce enterprise policies like governance and auditing and environment management while the application is deployed in the cloud. These cloud-based monitoring and management services can collect a multitude of events, analyze them, and identify critical information that requires additional remedial actions like adjusting capacity or provisioning new services. Additionally,

application management has to be supported with tools and processes required for managing other environments that might coexist, enabling efficient operations.

3.1 Migrating Application to Cloud

Cloud migration encompasses moving one or more enterprise applications and their IT environments from the traditional hosting type to the cloud environment, either public, private, or hybrid. Cloud migration presents an opportunity to significantly reduce costs incurred on applications. This activity comprises, of different phases like evaluation, migration strategy, prototyping, provisioning, and testing.

3.1.1 Phases of Cloud Migration

1. **Evaluation**: Evaluation is carried out for all the components like current infrastructure and application architecture, environment in terms of compute, storage, monitoring, and management, SLAs, operational processes, financial considerations, risk, security, compliance, and licensing needs are identified to build a business case for moving to the cloud.
2. **Migration strategy**: Based on the evaluation, a migration strategy is drawn—a hotplug strategy is used where the applications and their data and interface dependencies are isolated and these applications can be operationalized all at once. A fusion strategy is used where the applications can be partially migrated; but for a portion of it, there are dependencies based on existing licenses, specialized server requirements like mainframes, or extensive interconnections with other applications.

3. **Prototyping**: Migration activity is preceded by a prototyping activity to validate and ensure that a small portion of the applications are tested on the cloud environment with test data setup.
4. **Provisioning**: Premigration optimizations identified are implemented. Cloud servers are provisioned for all the identified environments, necessary platform softwares and applications are deployed, configurations are tuned to match the new environment sizing, and databases and files are replicated. All internal and external integration points are properly configured. Web services, batch jobs, and operation and management software are set up in the new environments.
5. **Testing**: Postmigration tests are conducted to ensure that migration has been successful. Performance and load testing, failure and recovery testing, and scale-out testing are conducted against the expected traffic load and resource utilization levels.

3.6.3 Approaches for Cloud Migration

The following are the four broad approaches for cloud migration that have been adopted effectively by vendors:

1. **Migrate existing applications**: Rebuild or rearchitect some or all the applications, taking advantage of some of the virtualization technologies around to accelerate the work. But, it requires top engineers to develop new functionality. This can be achieved over the course of several releases with the timing determined by customer demand.
2. **Start from scratch**: Rather than cannibalize sales, confuse customers with choice, and tie up engineers trying to rebuild existing application, it may be easier to start again. Many of the R&D decisions will be different now, and with some of the more sophisticated development environments, one can achieve more even with a small focused working team.
3. **Separate company**: One may want to create a whole new company with separate brand, management, R&D, and sales. The investment and internet protocol (IP) may come from the existing company, but many of the conflicts disappear once a new *born in the cloud* company is established. The separate company may even be a subsidiary of the existing company. What is important is that the new company can act, operate, and behave like a cloud-based start-up.
4. **Buy an existing cloud vendor**: For a large established vendor, buying a cloud-based competitor achieves two things. Firstly, it removes a competitor, and secondly, it enables the vendor to hit the ground running in the cloud space. The risk of course is that the innova- tion, drive, and operational approach of the cloud-based company are destroyed as it is merged into the larger acquirer.

3.7 Summary

Cloud computing has several concepts that must be understood before starting off with the details about the cloud, which include one of the important concepts of cloud architecture. It consists of a basic hierarchical structure with dependencies of components specified. Similarly, anatomy is also important as it describes the basic structure about the cloud, though it does not consider

any dependency as in architecture. Further, the cloud network connectivity that forms the core of the cloud model is important. The network is the base using which the cloud works. Similarly, cloud management is one of the important concepts that describe the way in which the cloud is managed,and it has two components: infrastructure management and application management. Both are important as both affect the QoS. Finally, an application should be successfully migrated to a cloud. An application will radiate its complete properties as a cloud only when it has perfectly migrated.

4

Cloud Service Models

Cloud computing provides computing resources, development platforms, and applications as a service to the end users. The information technology (IT) industries started subscribing the cloud services instead of buying the products. This chapter gives an insight into the three basic service modelsof cloud computing, namely, IaaS, PaaS, and SaaS. According to the servicesprovided and subscribed, the responsibilities of the end user and service may vary. This chapter also discusses the responsibilities of the end user and service providers of IaaS, PaaS, and SaaS. Characteristics, suitability, andpros and cons of different cloud service models are also discussed in this

chapter along with the summary of popular service providers. At the end, this chapter gives a brief idea about other cloud service models such as NaaS, StaaS, Database as a Service (DBaaS), Security as a Service (SECaaS), and Identity as a Service (IDaaS).

5.1 Introduction

Cloud computing is a model that enables the end users to access the shared pool of resources such as compute, network, storage, database, and application as an on-demand service without the need to buy or own it. The services are provided and managed by the service provider, reducing the management effort from the end user side. The essential characteristics of the cloud include on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. The National Institute of Standards and Technology (NIST) defines three basic service models, namely, IaaS, PaaS, and SaaS, as shown in Figure 5.1.

The NIST definition of the three basic service models is given as follows:

1. **IaaS**: The ability given to the infrastructure architects to deploy or run any software on the computing resources provided by the ser- vice provider. Here, the underlying infrastructures such as compute, network, and storage are managed by the service provider. Thus, the infrastructure architects are exempted from maintaining the data center or underlying infrastructure. The end users are responsible for managing applications that are running on top of the service

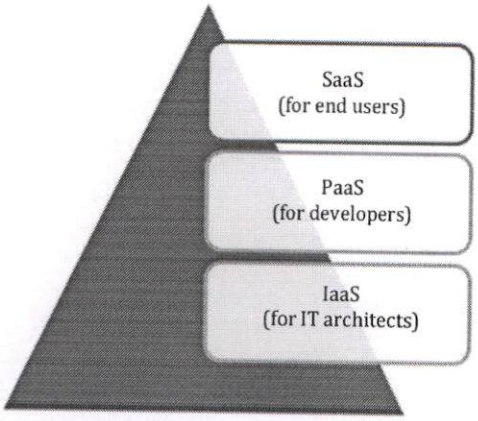


FIGURE 5.1
Basic cloud service models.

provider cloud infrastructure. Generally, the IaaS services are provided from the service provider cloud data center. The end users can access the services from their devices through web command line interface (CLI) or application programming interfaces (APIs) provided by the service providers. Some of the popular IaaS provid-ers include Amazon Web Services (AWS), Google Compute Engine, OpenStack, and Eucalyptus.

2. **PaaS:** The ability given to developers to develop and deploy an application on the development platform provided by the service provider. Thus, the developers are exempted from managing the development platform and underlying infrastructure. Here, the developers are responsible for managing the deployed application and configur- ing the development environment. Generally, PaaS services are provided by the service provider on an on-premise or dedicated or hosted cloud infrastructure. The developers can access the develop-ment platform over the Internet through web CLI, web user interface(UI), and integrated development environments (IDEs). Some of the popular PaaS providers include Google App Engine, Force.com, Red Hat OpenShift, Heroku, and Engine Yard.
3. **SaaS:** The ability given to the end users to access an application over the Internet that is hosted and managed by the service provider. Thus, the end users are exempted from managing or controlling an application, the development platform, and the underlying infrastructure. Generally, SaaS services are hosted in service provider–managed or service provider–hosted cloud infrastructure. The end users can access the services from any thin clients or web browsers. Some of the popular SaaS providers include Saleforce.com, Google Apps, and Microsoft office 365.

The different cloud service models target different audiences. For example, the IaaS model targets the information technology (IT) architects, PaaS targets the developers, and SaaS targets the end users. Based on the services subscribed, the responsibility of the targeted audience may vary as shown in Figure 5.2.

In IaaS, the end users are responsible for maintaining the development platform and the application running on top of the underlying infrastructure. The IaaS providers are responsible for maintaining the underlying hardware as shown in Figure 5.2a. In PaaS, the end users are responsible for manag-

ing the application that they have developed. The underlying infrastructure will be maintained by the infrastructure provider as shown in Figure 5.2b. In SaaS, the end user is free from maintaining the infrastructure, develop- ment platform, and application that they are using. All the maintenance willbe carried out by the SaaS providers as shown Figure 5.2c.

The different service models of cloud computing can be deployed and delivered through any one of the cloud deployment models. The NISTdefines four different types of cloud deployment models, namely, public cloud, private cloud, community cloud, and hybrid cloud. The public cloud isprovided for the general public. The private cloud is used by an organization for its multiple business units. The community cloud is for some group of organization with the same goals. The hybrid cloud is any combination of the public, private, and community clouds. The service delivery of cloud services through different deployment models is shown in Figure 5.3.

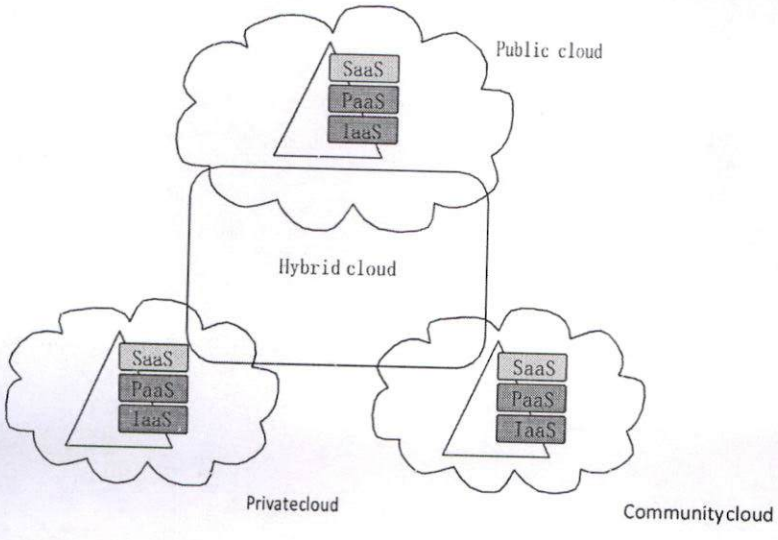


FIGURE 5.3
Deployment and delivery of different cloud service delivery models.

This chapter discusses about the characteristics, suitability, and pros and cons of different cloud service models. Additionally, this chapter gives the summary of popular IaaS, PaaS, and SaaS providers.

5.1 Infrastructure as a Service

IaaS changes the way that the compute, storage, and networking resources are consumed. In traditional data centers, the computing power is consumed by having physical access to the infrastructure. IaaS changes the computing from a physical infrastructure to a virtual infrastructure. IaaS provides virtual computing, storage, and network resources by abstracting the physical resources. Technology *virtualization* is used to providethe virtual resources. All the virtual resources are given to the virtual machines (VMs) that are configured by the service provider. The end users or IT architects will use the infrastructure resources in the form of VMs as shown in Figure 5.4.

The targeted audience of IaaS is the IT architect. The IT architect can design

virtual infrastructure, network, load balancers, etc., based on their needs. The IT architects need not maintain the physical servers as it is

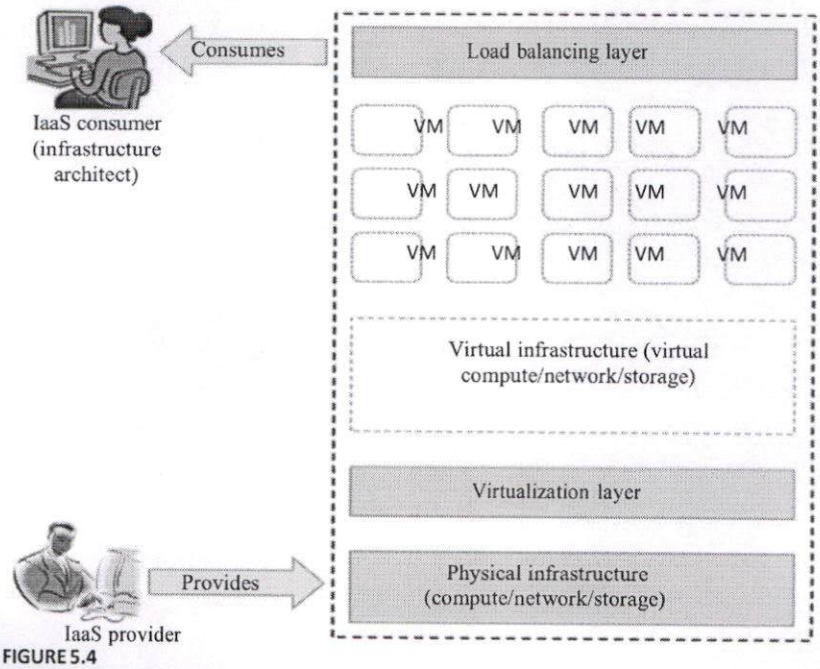


FIGURE 5.4
Overview of IaaS.

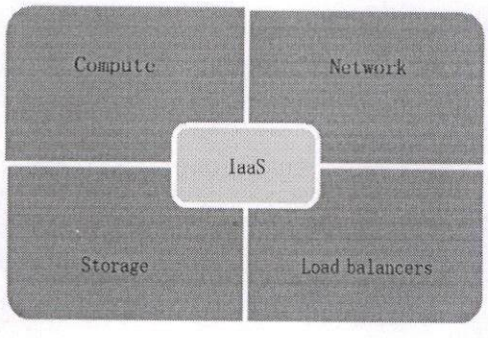


FIGURE 5.5
Services provided by IaaS providers.

maintained by the service providers. The physical infrastructure can be maintained by the service providers themselves. Thus, it eliminates or hides the complexity of maintaining the physical infrastructure from the IT architects. A typical IaaS provider may provide the flowing services as shown in Figure 5.5:

4. **Compute**: Computing as a Service includes virtual central processing units (CPUs) and virtual main memory for the VMs that are provi-

sioned to the end users.

5. **Storage**: STaaS provides back-end storage for the VM images. Some of the IaaS providers also provide the back end for storing files.
6. **Network**: Network as a Service (NaaS) provides virtual networking components such as virtual router, switch, and bridge for the VMs.
7. **Load balancers**: Load Balancing as a Service may provide load balancing capability at the infrastructure layer.

5.2.1 Characteristics of IaaS

IaaS providers offer virtual computing resources to the consumers on a pay-as-you-go basis. IaaS contains the characteristics of cloud computing such as on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. Apart from all these, IaaS has its own unique characteristics as follows:

I. **Web access to the resources**: The IaaS model enables the IT users to access infrastructure resources over the Internet. When accessing a huge computing power, the IT user need not get physical access to the servers. Through any web browsers or management console, theusers can access the required infrastructure.

II. **Centralized management:** Even though the physical resources are dis-tributed, the management will be from a single place. The resourcesdistributed across different parts can be controlled from any man- agement console. This ensures effective resource management and effective resource utilization.

III. **Elasticity and dynamic scaling:** IaaS provides elastic services where the usage of resources can be increased or decreased according to therequirements. The infrastructure need depends on the load on the appli-cation. According to the load, IaaS services can provide the resources. The load on any application is dynamic and IaaS services are capable ofproving the required services dynamically.

IV. **Shared infrastructure**: IaaS follows a one-to-many delivery model andallows multiple IT users to share the same physical infrastructure. The different IT users will be given different VMs. IaaS ensures highresource utilization.

V. **Preconfigured VMs:** IaaS providers offer preconfigured VMs with operating systems (OSs), network configuration, etc. The IT users can select any kind of VMs of their choice. The IT users are free to configure VMs from scratch. The users can directly start using the VMs as soon as they subscribed to the services.

VI. ***Metered services*:** IaaS allows the IT users to rent the computingresources instead of buying it. The services consumed by the IT userwill be measured, and the users will be charged by the IaaS provid-ers based on the amount of usage.

5.2.1 Suitability of IaaS

IaaS reduces the total cost of ownership (TCO) and increases the return on investment (ROI) for start-up companies that cannot invest more in buying infrastructure.

IaaS can be used in the following situations:

1. **Unpredictable spikes in usage**: When there is a significant spike in

usageof computing resources, IaaS is the best option for IT industries. When demand is very volatile, we cannot predict the spikes and troughs interms of demand of the infrastructure. In this situation, we cannot add or remove infrastructure immediately according to the demand in a traditional infrastructure. If there is an unpredictable demand ofinfrastructure, then it is recommended to use IaaS services.

2. **Limited capital investment**: New start-up companies cannot invest more on buying infrastructure for their business needs. And so by using IaaS, start-up companies can reduce the capital investment on hardware. IaaS is the suitable option for start-up companies with less capital investment on hardware.
3. **Infrastructure on demand:** Some organizations may require large infrastructure for a short period of time. For this purpose, an organization cannot afford to buy more on-premise resources. Instead, they can rent the required infrastructure for a specific period of time. IaaS best suits the organizations that look for infrastructure on demand or for a short time period.

IaaS helps start-up companies limit its capital expenditure. While it is widely used by start-up companies, there are some situations where IaaS may not be the best option. In following situations, IT users should avoid using the IaaS:

1. **When regulatory compliance does not allow off-premise hosting:** For somecompanies, its regulation may not allow the application and data tobe hosted on third-party off-premise infrastructure.
2. **When usage is minimal**: When the usage is minimal and the available on-premise infrastructure itself is capable of satisfying their needs.
3. **When better performance is required:** Since the IaaS services are accessedthrough the Internet, sometimes the performance might be not as expected due to network latency.
4. **When there is a need for more control on physical infrastructure:** Some organizations might require physical control over the underlying infrastructure. As the IaaS services are abstracted as virtual resources, it is not possible to have more control on underlying phys-ical infrastructure.

5.2.2 Pros and Cons of IaaS

Being one of the important service models of cloud computing, IaaS provides lot of benefits to the IT users. The following are the benefits provided by IaaS:

1. **Pay-as-you-use model**: The IaaS services are provided to the customerson a pay-per-use basis. This ensures that the customers are requiredto pay for what they have used. This model eliminates the unneces-sary spending on buying hardware.
2. **Reduced TCO:** Since IaaS providers allow the IT users to rent the com-puting resources, they need not buy physical hardware for running their business. The IT users can rent the IT infrastructure

rather thanbuy it by spending large amount. IaaS reduces the need for buying hardware resources and thus reduces the TCO.

3. **Elastic resources**: IaaS provides resources based on the current needs.IT users can scale up or scale down the resources whenever they want. This dynamic scaling is done automatically using some load balancers. This load balancer transfers the additional resource request to the new server and improves application efficiency.
4. **Better resource utilization**: Resource utilization is the most important criteria to succeed in the IT business. The purchased infrastructure should be utilized properly to increase the ROI. IaaS ensures better resource utilization and provides high ROI for IaaS providers.
5. **Supports Green IT**: In traditional IT infrastructure, dedicated servers are used for different business needs. Since many servers are used, the power consumption will be high. This does not result in Green IT. In IaaS, the need of buying dedicated servers is eliminated as single infrastructure is shared between multiple customers, thus reducing the number of servers to be purchased and hence the power consumption that results in Green IT.

Even though IaaS provides cost-related benefits to small-scale industries, it lacks in providing security to the data. The following are the drawbacks of IaaS:

1. **Security issues**: Since IaaS uses virtualization as the enabling technology, hypervisors play an important role. There are many attacks that target the hypervisors to compromise it. If hypervisors get compromised, then any VMs can be attacked easily. Most of the IaaS providers are not able to provide 100% security to the VMs and the data stored on the VMs.
2. **Interoperability issues**: There are no common standards followed among the different IaaS providers. It is very difficult to migrate any VM from one IaaS provider to the other. Sometimes, the customers might face the vendor lock-in problem.
3. **Performance issues**: IaaS is nothing but the consolidation of available resources from the distributed cloud servers. Here, all the distributed servers are connected over the network. Latency of the network plays an important role in deciding the performance. Because of latency issues, sometimes the VM contains issues with its performance.

5.2.3 Summary of IaaS Providers

There are many public and private IaaS providers in the market who provides infrastructure services to the end users. Table 5.1 provides the summary of popular infrastructure providers.

In the table, the popular IaaS providers are classified based on the license, deployment model, and supported host OS, guest OS, and hypervisors. The end user may choose any IaaS provider that matches their needs. Generally,

TABLE 5.1

Summary of Popular IaaS Providers

Provider	License	Deployment Model	Host OS	Guest OS	Supported Hypervi
Amazon Web Services	Proprietary	Public	Not available	Red Hat Linux, Windows Server, SuSE Linux, Ubuntu, Fedora, Debian, CentOS, Gentoo Linux, Oracle Linux, and FreeBSD	Xen
Google Compute Engine	Proprietary	Public	Not available	Debian 7 Wheezy, CentOS 6, RedHat Enterprise Linux, SUSE, Windows Server, CoreOS, FreeBSD, and SELinux	KVM
Microsoft Windows Azure	Proprietary	Public	Not available	Windows Server, CentOS, FreeBSD, openSUSE Linux, and Oracle Enterprise Linux	Windows Azure hype
Eucalyptus	GPLv3	Private and hybrid	Linux	Linux and Windows	Xen, KVM, Vmware
Apache CloudStack	Apache 2	Private	Linux	Windows, Linux, and various versions of BSD	KVM, vSphere, XenS XCP
OpenNebula	Apache 2	Private, public, and hybrid	CentOS, Debian, and openSUSE	Microsoft Windows and Linux	Xen, KVM, Vmware
OpenStack	Apache 2	Private and public	CentOS, Debian, Fedora, RHEL, openSUSE, and Ubuntu	CentOS, Ubuntu, Microsoft Windows, and FreeBSD	libvirt, Hyper-V, VMwa XenServer 6.2, barer docker, Xen, LXC via l

public IaaS consumers need not consider the host OS as it is maintained by the service provider. In managing the private cloud, the users should seethe supported host OS. However, most of the private IaaS supports popu- lar guest OS, fully depending on the hypervisor that the IaaS providers are supporting.

5.1 Platform as a Service

PaaS changes the way that the software is developed and deployed. In tra- ditional application development, the application will be developed locally and will be hosted in the central location. In stand-alone application develop- ment, the applications will be developed and delivered as executables. Mostof the applications developed by traditional development platforms result ina licensing-based software, whereas PaaS changes the application develop- ment from local machine to online. PaaS providers provide the developmentPaaS from the data center. The developers can consume the services over the Internet as shown in Figure 5.6.

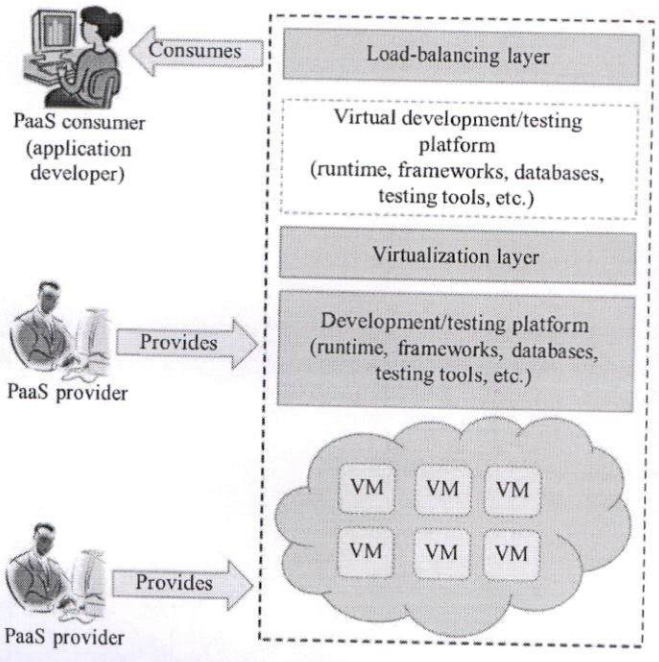


FIGURE 5.6
Overview of PaaS.

PaaS allows the developers to develop their application online and also allows them to deploy immediately on the same platform. PaaS consumers or developers can consume language runtimes, application frameworks, databases, message queues, testing tools, and deployment tools as a ser-vice over the Internet. Thus, it reduces the complexity of buying and maintaining different tools for developing an application. Typical PaaS providers may provide programming languages, application frameworks, databases, and testing tools as shown in Figure 5.7. Some of the PaaS pro- viders also provide build tools, deployment tools, and software load bal- ancers as a service:

1. **Programming languages:** PaaS providers provide a wide variety of programming languages for the developers to develop applications.Some of the popular programming languages provided by PaaS vendors are Java, Perl, PHP, Python, Ruby, Scala, Clojure, and Go.

2. **Application frameworks**: PaaS vendors provide application frame- works that simplify the application development. Some of the popular application development frameworks provided by a PaaS provider include Node.js, Rails, Drupal,

Joomla, WordPress, Django,EE6, Spring, Play, Sinatra, Rack, and Zend.

3. **Database**: Since every application needs to communicate with the databases, it becomes a must-have tool for every application. PaaS providers are providing databases also with their PaaS plat- forms. The popular databases provided by the popular PaaS ven- dors are ClearDB, PostgreSQL, Cloudant, Membase, MongoDB, and Redis.
4. **Other tools**: PaaS providers provide all the tools that are required to develop, test, and deploy an application.

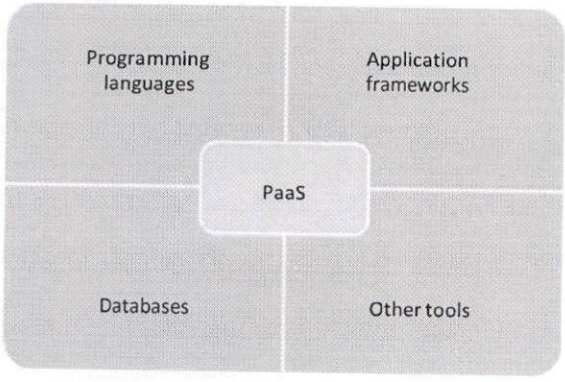


FIGURE 5.7
Services provided by PaaS providers.

5.3.1 Characteristics of PaaS

PaaS development platforms are different from the traditional application development platforms. The following are the essential characteristics that make PaaS unique from traditional development platforms:

1. **All in one**: Most of the PaaS providers offer services to develop, test,deploy, host, and maintain applications in the same IDE. Additionally, many service providers provide all the programming languages, frameworks, databases, and other development-related services that make developers choose from a wide variety of development platforms.
2. **Web access to the development platform**: A typical development plat- form uses any IDEs for developing applications. Typically, the IDE will be installed in the developer's machines. But, PaaS provides web access to the development platform. Using web UI, any devel- oper can get access to the development platform. The web-based UIhelps the developers create, modify, test, and deploy different appli-cations on the same platform.
3. **Offline access**: A developer may not be able to connect to the Internetfor a whole day to access the PaaS services. When there is no Internet connectivity, the developers should be allowed to work offline. To enable offline development, some of the PaaS providers allow the developer to synchronize their local IDE with the PaaS services. Thedevelopers can develop an application locally and deploy it online whenever they are connected to the Internet.
4. **Built-in scalability**: Scalability is an important requirement for the new-generation web or SaaS applications. It is very difficult to enable thedynamic scalability for any application developed using traditional development platforms. But, PaaS services provide built-in scalability toan application that is developed using any particular PaaS. This ensuresthat the application is capable of handling varying loads efficiently.

5. **Collaborative platform**: Nowadays, the development team consists of developers who are working from different places. There is a need for a common platform where the developers can collaboratively work together on the same project. Most of the PaaS services pro- vide support for collaborative development. To enable collaborationamong developers, most of the PaaS providers provide tools for proj- ect planning and communication.

5.3.2 **Diverse client tools**: *To make the development easier, PaaS providersprovide a wide variety of client tools to help the developer. The client tools include CLI, web CLI, web UI, REST API, and IDE. The developers can choose any tools of their choice. These client tools are also capable of handling billing and subscription management Suitability of PaaS*

Most of the start-up SaaS development companies and independent softwarevendors (ISVs) widely use PaaS in developing an application. PaaS technol- ogy is getting attention from other traditional software development compa-nies also. PaaS is a suitable option for the following situations:

1. **Collaborative development**: To increase the time to market and devel- opment efficiency, there is a need for a common place where the development team and other stakeholders of the application can col-laborate with each other. Since PaaS services provide a collabora- tive development environment, it is a suitable option for applicationsthat need collaboration among developers and other third parties tocarry out the development process.
2. **Automated testing and deployment**: Automated testing and building of an application are very useful while developing applicationsat a very short time frame. The automated testing tools reducethe time spent in manual testing tools. Most of the PaaS services offer automated testing and deployment capabilities. The develop- ment team needs to concentrate more on development rather than testing and deployment. Thus, PaaS services are the best option where there is a need for automated testing and deployment of the applications.
3. **Time to market**: The PaaS services follow the iterative and incrementaldevelopment methodologies that ensure that the application is in themarket as per the time frame given. For example, the PaaS services are the best option for application development that uses agile devel-opment methodologies. If the software vendor wants their applica- tion to be in the market as soon as possible, then the PaaS services are the best option for the development.

PaaS is used widely to accelerate the application development process to ensure the time to market. Most of the start-up companies and ISVs started migrating to the PaaS services. Even though it is used widely, there are somesituations where PaaS may not be the best option:

1. **Frequent application migration**: The major problem with PaaS servicesare vendor lock-in. Since there are no common standards followed among PaaS providers, it is very difficult to migrate the applicationfrom one PaaS provider to the other.
2. **Customization at the infrastructure level**: PaaS is an abstracted service, andthe PaaS users do not have full control over the underlying infrastruc-ture. There are some application development platforms that need someconfiguration or customization of underlying infrastructure. In these

   situations, it is not possible to customize the underlying infrastructurewith PaaS. If the application development platform needs any configu-ration at the hardware level, it is not recommended to go for PaaS.

3. **Flexibility at the platform level**: PaaS provides template-based appli- cations where all the different programming languages, databases, and message queues are predefined. It is an advantage if the applica-tion is a generic application.
4. **Integration with on-premise application**: A company might have used PaaS services for some set of applications. For some set of applica- tions, they might have used on-premise platforms. Since many PaaS services use their own proprietary technologies to define the appli- cation stack, it may not match with the on-premise application stack. This makes the integration of application hosted in on-premise plat-form and PaaS platform a difficult job.

5.3.3 Pros and Cons of PaaS

The main advantage of using PaaS is that it hides the complexity of main- taining the platform and underlying infrastructure. This allows the devel- opers to work more on implementing the important functionalities of the application. Apart from this, the PaaS has the following benefits:

1. **Quick development and deployment:** PaaS provides all the required development and testing tools to develop, test, and deploy the soft-ware in one place. Most of the PaaS services automate the testing and deployment process as soon as the developer completes the devel- opment. This speeds up application development and deployment than traditional development platforms.
2. **Reduces TCO**: The developers need not buy licensed development andtesting tools if PaaS services are selected. Most of the traditional devel-opment platforms requires high-end infrastructure for its working, which increases the TCO of the application development company. But, PaaS allows the developers to rent the software, development platforms, and testing tools to develop, build, and deploy the applica- tion. PaaS does not require high-end infrastructure also to develop the application, thus reducing the TCO of the development company.
3. **Supports agile software development**: Nowadays, most of the new-genera- tion applications are developed using agile methodologies. Many ISVs and SaaS development companies started adopting agile methodolo- gies for application development. PaaS services support agile method- ologies that the ISVs and other development companies are looking for.
4. **Different teams can work together**: The traditional development plat- form does not have extensive support for collaborative development.

   PaaS services support developers from different places to worktogether on the same project. This is possible because of the online common development platform provided by PaaS providers.
5. **Ease of use**: The traditional development platform uses any one of CLI- or IDE-based interfaces for development. Some developers maynot be familiar with the interfaces provided by the application devel-opment platform. This makes the development job a little bit dif- ficult. But, PaaS provides a wide variety of client tools such as CLI, web CLI, web UI, APIs, and IDEs. The developers are free to chooseany client tools of their choice. Especially, the web UI–based PaaS services increase the usability of the development platform for all types of developers.
6. **Less maintenance overhead**: In on-premise applications, the develop- ment company or software vendor is responsible for maintaining the underlying hardware. They need to recruit skilled administra- tors to maintain the servers. This overhead is eliminated by the PaaS services as the underlying infrastructure is maintained by the infra-structure providers. This gives freedom to developers to

work on theapplication development.

7. **Produces scalable applications**: Most of the applications developed using PaaS services are web application or SaaS application. These applications require better scalability on the extra load. For handlingextra load, the software vendors need to maintain an additional server. It is very difficult for a new start-up company to provide extraservers based on the additional load. But, PaaS services are provid- ing built-in scalability to the application that is developed using thePaaS platform.

PaaS provides a lot of benefits to developers when compared to the tradi- tional development environment. On the other hand, it contains drawbacks,which are described in the following:

1. **Vendor lock-in:** The major drawback with PaaS providers are vendorlock-in. The main reason for vendor lock-in is lack of standards. Thereare no common standards followed among the different PaaS provid-ers. The other reason for vendor lock-in is proprietary technologies used by PaaS providers. Most of the PaaS vendors use the proprietarytechnologies that are not compatible with the other PaaS providers. The vendor lock-in problem of PaaS services does not allow the appli- cations to be migrated from one PaaS provider to the other.
2. **Security issues:** Like in the other cloud services, security is one ofthe major issues in PaaS services. Since data are stored in off-premise third-party servers, many developers are afraid to go for PaaS

   services. Of course, many PaaS providers provide mechanisms to protect the user data, and it is not sufficient to feel the safety of on- premise deployment. When selecting the PaaS provider, the devel- oper should review the regulatory, compliance, and security policies of the PaaS provider with their own security requirements. If not properly reviewed, the developers or users are at the risk of data security breach.
3. **Less flexibility:** PaaS providers do not give much freedom for the developers to define their own application stack. Most of the PaaS providers provide many programming languages, databases, and other development tools. But, it is not extensive and does not satisfy alldeveloper needs. Only some of the PaaS providers allow developersto extend the PaaS tools with the custom or new programming lan- guages. Still most of the PaaS providers do not provide flexibility tothe developers.
4. **Depends on Internet connection:** Since the PaaS services are delivered over the Internet, the developers should depend on Internet connec-tivity for developing the application. Even though some of the pro- viders allow offline access, most of the PaaS providers do not allow offline access. With slow Internet connection, the usability and effi- ciency of the PaaS platform do not satisfy the developer requirements.

5.3.4 Summary of PaaS Providers

PaaS providers are more in the IT market for public as well as the private clouds. Table 5.2 gives a summary of popular private and public PaaS providers.

TABLE 5.2

Summary of Popular PaaS Providers

Provider	License	Deployment Model	Supported Languages	Supported Frameworks	Supported Databases	Client Tools
Cloud Foundry	Open source and proprietary	Public	Python, PHP, Java, Groovy, Scala, and Ruby	Spring, Grails, Play, Node.js, Lift, Rails, Sinatra, and Rack	MySQL, PostgreSQL, MongoDB, and Redis	cf. CLI, IDEs, and build tools
Google App Engine	Proprietary	Public	Python, Java, Groovy, JRuby, Scala, Clojure, Go, and PHP	Django, CherryPy, Pyramid, Flask, web2py, and webapp2.	Google Cloud SQL, Datastore, BigTable, and Blobstore	APIs
Heroku	Proprietary	Public	Ruby, Java, Scala, Clojure and Python, PHP, and Perl	Rails, Play, Django, and Node.js.	ClearDB, PostgreSQL, Cloudant, Membase, MongoDB, and Redis	CLIand RESTful API
Microsoft Windows Azure	Proprietary	Public	.Net, PHP, Python, Ruby, and Java	Django, Rails, Drupal, Joomla, WordPress, DotNetNuke, and Node.js.	SQL Azure, MySQL, MongoDB, and CouchDB	RESTful API and IDEs
Red Hat OpenShift Online	Proprietary	Public	Java, Ruby, Python, PHP, and Perl	Node.js, Rails, Drupal, Joomla, WordPress, Django,EE6, Spring, Play, Sinatra, Rack, and Zend.	MySQL, PostgreSQL, and MongoDB	Web UI, APIs CLI, and IDE
ActiveState Stackato	Proprietary	Private	Java, Perl, PHP, Python, Ruby, Scala, Clojure, andGo	Spring, Node.js, Drupal, Joomla, WordPress, Django, Rails, and Sinatra.	MySQL, PostgreSQL, MongoDB, and Redis	CLI and IDE
Apprenda	Proprietary	Private	.Net and Java	Most of the frameworks form .Net.	SQL Server	REST APIs
CloudBees	Proprietary	Private	Java, Groovy, and Scala	Spring, JRails, JRuby, and Grails.	MySQL, PostgreSQL, MongoDB, and CouchDB	API, SDK, and IDEs
Cumulogic	Proprietary	Private	Java, PHP, and Python	Spring and Grails.	MySQL, MongoDB, and Couchbase	RESTful API
Gigaspaces Cloudify	Open source	Private	Any programming language specified by recipe	Rails, Play, and others.	MySQL, MongoDB, Couchbase, Cassandra, and others	CLI, web UI, REST API

5.2 Software as a Service

SaaS changes the way the software is delivered to the customers. In the tra- ditional software model, the software is delivered as a license-based product that needs to be installed in the end user device. Since SaaS is delivered as anon-demand service over the Internet, there is no need to install the softwareto the end user's devices. SaaS services can be accessed or disconnected at any time based on the end user's needs. SaaS services can be accessed from any lightweight web browsers on any devices such as laptops, tablets, and smartphones. Some of the SaaS services can be accessed from a thin client that does not contain much storage space and cannot run much software likethe traditional desktop

PCs. The important benefits of using thin clients for accessing the SaaS application are as follows: it is less vulnerable to attack, has a longer life cycle, consumes less power, and is less expensive. A typical

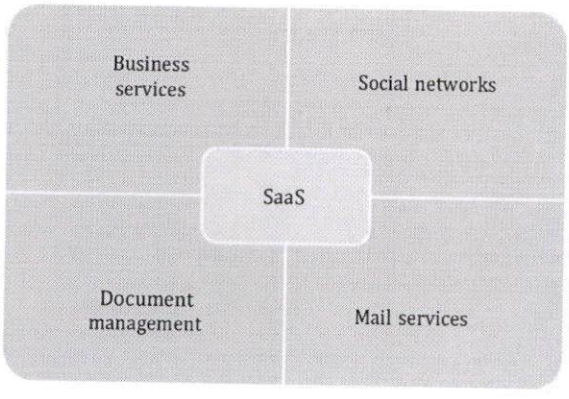


FIGURE 5.8
Services provided by SaaS Providers.

SaaS provider may provide business services, social networks, document management, and mail services as shown in Figure 5.8:

1. **Business services:** Most of the SaaS providers started providing a vari-ety of business services that attract start-up companies. The business SaaS services include ERP, CRM, billing, sales, and human resources.
2. **Social networks:** Since social networking sites are extensively usedby the general public, many social networking service providers adopted SaaS for their sustainability. Since the number of users of the social networking sites is increasing exponentially, cloud com- puting is the perfect match for handling the variable load.
3. **Document management**: Since most of the enterprises extensively useelectronic documents, most of the SaaS providers started provid- ing services that are used to create, manage, and track electronic documents.
4. **Mail services**: E-mail services are currently used by many people. Thefuture growth in e-mail usage is unpredictable. To handle the unpre-dictable number of users and the load on e-mail services, most of the e-mail providers started offering their services as SaaS services.

5.4.1 Characteristics of SaaS

SaaS services are different and give more benefits to end users than the tra- ditional software. The following are the essential characteristics of SaaS ser- vices that make it unique from traditional software:

One to many: SaaS services are delivered as a one-to-many model where a single instance of the application can be shared by multiple tenants or customers.

1. **Web access:** SaaS services provide web access to the software. It allowsthe end user to access the application from any location if the deviceis connected to the Internet.
2. **Centralized management**: Since SaaS services are hosted and man- aged from the central location, management of the SaaS applica- tion becomes easier. Normally, the SaaS providers will perform the automatic updates that ensure that each

tenant is accessing the mostrecent version of the application without any user-side updates.

3. **Multidevice support:** SaaS services can be accessed from any end userdevices such as desktops, laptops, tablets, smartphones, and thin clients.
4. **Better scalability:** Since most of the SaaS services leverage PaaS and IaaS for its development and deployment, it ensures a better scalabil-ity than the traditional software. The dynamic scaling of underlying cloud resources makes SaaS applications work efficiently even withvarying loads.
5. **High availability:** SaaS services ensure the 99.99% availability of user data as proper backup and recovery mechanisms are implemented at the back end.
6. **API integration:** SaaS services have the capability of integrating with other software or service through standard APIs.

5.4.2 Suitability of SaaS

SaaS is popular among individuals and start-up companies because of the benefits it provides. Most of the traditional software users are looking for SaaS versions of the software as SaaS has several advantages over traditionalapplications. SaaS applications are the best option for the following:

1. **On-demand software**: The licensing-based software model requires buying full packaged software and increases the spending on buy- ing software. Some of the occasionally used software does not give any ROI. Because of this, many end users are looking for a softwarethat they can use as and when they needed. If the end users are looking for on-demand software rather than the licensing-basedfull-term software, then the SaaS model is the best option.
2. **Software for start-up companies:** When using any traditional software,the end user should buy devices with minimum requirements speci-fied by the software vendor. This increases the investment on buy- ing hardware for start-up companies. Since SaaS services do not require high-end infrastructure for accessing, it is a suitable option for start-up companies that can reduce the initial expenditure on buying high-end hardware.
3. **Software compatible with multiple devices:** Some of the applicationslike word processors or mail services need better accessibility from different devices. The SaaS applications are adaptable with almost all the devices.
4. **Software with varying loads:** We cannot predict the load on popular applications such as social networking sites. The user may connect or disconnect from applications anytime. It is very difficult to handlevarying loads with the traditional infrastructure. With the dynamic scaling capabilities, SaaS applications can handle varying loads effi- ciently without disrupting the normal behavior of the application.

Most of the traditional software vendors moved to SaaS business as it is an emerging software delivery model that attracts end users. But still many tra-ditional applications do not have its SaaS versions. This implies that SaaS applications may not be the best option for all types of software. The SaaS delivery model is not the best option for the applications mentioned in the following:

1. **Real-time applications**: Since SaaS applications depend on Internet con-nectivity, it may not work better with low Internet speed. If data arestored far away from the end user, the latency issues may delay the data retrieval timings. Real-time

applications require fast processing ofdata that may not be possible with the SaaS applications because of the dependency on high-speed Internet connectivity and latency issues.

2. **Applications with confidential data:** Data security, data governance, and data compliance are always issues with SaaS applications. Since data are stored with third-party service providers, there is no suretythat our data will be safe. If the stored confidential data get lost, it will make a serious loss to the organization. It is not recommended to go for SaaS for applications that handle confidential data.
3. **Better on-premise application:** Some of the on-premise applications might fulfill all the requirements of the organization. In such situa- tions, migrating to the SaaS model may not be the best option.

5.4.3 Pros and Cons of SaaS

SaaS applications are used by a wide range of individuals and start-up industries for its cost-related benefits. Apart from the cost-related benefits, SaaS services provide the following benefits:

1. **No client-side installation:** SaaS services do not require client-side installation of the software. The end users can access the services directly from the service provider data center without any instal- lation. There is no need of high-end hardware to consume SaaS

services. It can be accessed from thin clients or any handheld devices,thus reducing the initial expenditure on buying high-end hardware.

2. **Cost savings:** Since SaaS services follow the utility-based billing or pay-as-you-go billing, it demands the end users to pay for what they have used. Most of the SaaS providers offer different sub- scription plans to benefit different customers. Sometimes, the generic SaaS services such as word processors are given for free to the end users.
3. **Less maintenance:** SaaS services eliminate the additional overhead of maintaining the software from the client side. For example, in the traditional software, the end user is responsible for performing bulkupdates. But in SaaS, the service provider itself maintains the auto- matic updates, monitoring, and other maintenance activities of the applications.
4. **Ease of access:** SaaS services can be accessed from any devices if itis connected to the Internet. Accessibility of SaaS services is not restricted to any particular devices. It is adaptable to all the devices as it uses the responsive web UI.
5. **Dynamic scaling:** SaaS services are popularly known for elastic dynamic scaling. It is very difficult for on-premise software to pro- vide dynamic scaling capability as it requires additional hardware. Since the SaaS services leverage elastic resources provided by cloud computing, it can handle any type of varying loads without disrupt-ing the normal behavior of the application.
6. **Disaster recovery:** With proper backup and recovery mechanisms, rep-licas are maintained for every SaaS services. The replicas are distrib-uted across many servers. If any server fails, the end user can accessthe SaaS from other servers. It eliminates the problem of single pointof failure. It also ensures the high availability of the application.
7. **Multitenancy**: Multitenancy is the ability given to the end users to share a single instance of the application. Multitenancy increases resource utilization from the service provider side.

Even though SaaS services are used by many individuals and start-up indus-tries, the adoption from the large industries is very low. The major problem with SaaS services is security to the data. All companies are worried about the security of their data that are hosted in the service provider data center.

The following are the major problems with SaaS services:

1. **Security:** Security is the major concern in migrating to SaaS appli- cation. Since the SaaS application is shared between many endusers, there is a possibility of data leakage. Here, the data are storedin the service provider data center. We cannot simply trust some third-party service provider to store our company-sensitive and

TABLE 5.3

Summary of Popular SaaS Providers

Provider	Services Provided
Salseforce.com	On-demand CRM solutions
Google Apps	Gmail, Google Calendar, Talk, Docs, and SitesMicrosoft Office 356 Online office suite, software, plus services
NetSuite	ERP, accounting, order management, inventory, CRM, professionalservices automation (PSA), and e-commerce applications
Concur	Integrated travel and expense management solutions GoToMeeting Online meeting, desktop sharing, and video-conferencing softwareConstant Contact E-mail marketing, social-media marketing, online survey, event marketing, digital storefronts, and local deals tools
Workday, Inc.	Human capital management, payroll, and financial managementOracle CRM CRM applications
Intacct	Financial management and accounting software solutions

confidential data. The end user should be careful while selecting theSaaS provider to avoid unnecessary data loss.

2. **Connectivity requirements:** SaaS applications require Internet connec-tivity for accessing it. Sometimes, the end user's Internet connectiv- ity might be very slow. In such situations, the user cannot access theservices with ease. The dependency on high-speed Internet connec- tion is a major problem in SaaS applications.
3. **Loss of control:** Since the data are stored in a third-party and off- premise location, the end user does not have any control over the data. The degree of control over the SaaS application and data is lesser than the on-premise application.

5.4.4 Summary of SaaS Providers

There are many SaaS providers who provide SaaS services such as ERP, CRM, billing, document management, and mail services. Table 5.3 gives a summary of popular SaaS vendors in the market.

5.3 Other Cloud Service Models

The basic cloud services such as IaaS, PaaS, and SaaS are widely used by many individual and start-up companies. Now, cloud computing becomes the dominant technology that drives the IT world. Because of the extensive use of basic cloud services, the end users realize the importance and benefits

of specific services such as network, storage, and database. The basic cloud service models are the unified models that contain multiple services in it. Now, the end users' expectation changed, and they are expecting the indi- vidual services to be offered by service providers.

This makes most of the service providers to think about the separate services that meet end user requirements. Many service providers already started offering separate ser- vices such as network, desktop, database, and storage on demand as given in the following:

1. **NaaS** is an ability given to the end users to access virtual network services that are provided by the service provider. Like other cloud service models, NaaS is also a business model for delivering vir- tual network services over the Internet on a pay-per-use basis. In on-premise data center, the IT industries spent a lot of money to buy network hardware to manage in-house networks. But, cloud computing changes networking services into a utility-based service. NaaS allows network architects to create virtual networks, virtual network interface cards (NICs), virtual routers, virtual switches, and other networking components. Additionally, it allows the network architect to deploy custom routing protocols and enables the design of efficient in-network services, such as data aggregation, stream processing, and caching. Some of the popular services provided by NaaS include virtual private network (VPN), bandwidth on demand (BoD), and mobile network virtualization.
2. **Desktop as a Service (DEaaS)** is an ability given to the end users to use desktop virtualization without buying and managing their own infrastructure. DEaaS is a pay-per-use cloud service delivery model in which the service provider manages the back-end responsibilities of data storage, backup, security, and upgrades. The end users are responsible for managing their own desktop images, applications, and security. Accessing the virtual desktop provided by the DEaaS provider is device, location, and network independent. DEaaS ser- vices are simple to deploy, are highly secure, and produce better experience on almost all devices.
3. **STaaS** is an ability given to the end users to store the data on the storage services provided by the service provider. STaaS allows the end users to access the files at any time from any place. The STaaS provider provides the virtual storage that is abstracted from the physical storage of any cloud data center. STaaS is also a cloud busi- ness model that is delivered as a utility. Here, the customers can rent the storage from the STaaS provider. STaaS is commonly used as a backup storage for efficient disaster recovery.
4. **DBaaS** is an ability given to the end users to access the database ser-vice without the need to install and maintain it. The service provider

   is responsible for installing and maintaining the databases. The end users can directly access the services and can pay according to their usage. DBaaS automates the database administration pro- cess. The end users can access the database services through any API or web UIs provided by the service provider. The DBaaS eases the database administration process. Popular examples of DBaaS include SimpleDB, DynamoDB, MongoDB as a Service, GAE datas- tore, and ScaleDB.
5. **Data as a Service (DaaS)** is an ability given to the end users to access the data that are provided by the service provider over the Internet. DaaS provides data on demand. The data may include text, images, sounds, and videos. DaaS is closely related to other cloud service models such as SaaS and STaaS. DaaS can be easily integrated with SaaS or STaaS for providing the composite service. DaaS is highly used in geog- raphy data services and financial data services. The advantages of DaaS include agility, cost effectiveness, and data quality.
6. **SECaaS** is an ability given to the end user to access the security service provided by the service provider on a pay-per-use basis. In SECaaS, the service provider integrates their security services to benefit the end users. Generally, the SECaaS includes authentication, antivirus, antimalware/spyware, intrusion detection, and security event man- agement. The security services provided by the SECaaS providers are typically used for securing the on-premise or in-house infrastruc- ture and

applications. Some of the SECaaS providers include Cisco, McAfee, Panda Software, Symantec, Trend Micro, and VeriSign.

7. **IDaaS** is an ability given to the end users to access the authentica- tion infrastructure that is managed and provided by the third-partyservice provider. The end user of IDaaS is typically an organization or enterprise. Using IDaaS services, any organization can easilymanage their employees' identity without any additional overhead. Generally, IDaaS includes directory services, federated services, registration, authentication services, risk and event monitoring, single sign-on services, and identity and profile management.

The different new service models discussed in this section emerged after theintroduction of cloud computing. This field still evolves and introduces newservice models based on the end user's needs. Many researchers from indus- try and academia already started introducing their innovative idea to take cloud computing to the next level. Apart from the service models discussed in this chapter, cloud computing researchers are thinking to add more ser- vice models. Now, cloud computing moves to the scenario where everythingcan be given as a service. This can be termed as Everything as a Service (XaaS). In the future, we expect many new service models to achieve the goal

of XaaS. XaaS may include Backup as a Service (BaaS), Communication as a Service (CaaS), Hadoop as a Service (HaaS), Disaster Recovery as a Service (DRaaS), Testing as a Service (TaaS), Firewall as a Service (FWaaS), Virtual Private Network as a Service (VPNaaS), Load Balancers as a Service (LBaaS),Message Queue as a Service (MQaaS), and Monitoring as a Service (MaaS).

5.1 Summary

Cloud computing composes of three basic service models and four deploy- ment models. The service models include IaaS, PaaS, and SaaS, and the deployment models include private, public, community, and hybrid clouds. The service models decide the type of services provided by each service models. The deployment models decide the way of delivering the ser-vices. Cloud computing eliminates a lot of management overhead at each level. IaaS hides the complexity of maintaining the underlying hardware. PaaS hides the complexity of maintaining the development platform andthe hardware. In the same way, SaaS hides the complexity of maintain-ing the application, the development platform, and the hardware. All the basic cloud service models have an essential characteristic of cloud com- puting: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. Apart from these characteristics, each service model has its own unique characteristics. The characteristicsof IaaS include web access to the resources, centralized management, elas- ticity and dynamic scaling, shared infrastructure, preconfigured VMs, and metered services. The characteristics of PaaS include all in one, web access to the development platform, offline access, built-in scalability, collabora- tive platform, and diverse client tools. The characteristics of SaaS include one to many, web access, centralized management, multidevice support, better scalability, high availability, and API integration. Cost-based ben- efits of cloud services make individuals and start-up industries use cloud computing for their computing needs. Even though cloud services are used by many individuals and start-up industries, adaptability from large enter- prises is very low. We cannot use cloud services in all places. Generally, thecloud service can be used in start-up companies where the initial capital investment is very low. Cloud services cannot be used when the application uses more sensitive and confidential data. The general benefits of cloud ser-vices are cost savings,

elastic and dynamic scaling, and centralized man- agement. The general drawbacks include security issues, interoperability issues, and performance issues. Apart from the basic service models, there are other specific cloud services also provided by some vendors, including NaaS, STaaS, DBaaS, SECaaS, and IDaaS.

5

Cloud Service Providers

This chapter provides an overview of cloud services offered by various com-panies. We begin with the introduction to cloud services. Subsequent sections talk about companies like Amazon, Microsoft, Google, EMC, Salesforce, and IBM that provide various tools and services in order to give cloud support. Each section briefly describes cloud features supported by these companies. It also gives an idea of tools and technologies adapted by companies in orderto provide services to the users. In this chapter, we focus on giving readers brief information about various tools and technologies provided by different companies. After reading this chapter, the reader will be able to distinguish different services provided by various companies and make appropriate choices as per the requirement.

Introduction

Cloud computing is one of the most popular buzzwords used these days. It is the upcoming technology provisioning resources to the consumers in the form of different services like software, infrastructure, platform, and security. Services are made available to users on demand via the Internet from a cloud computing provider's servers as opposed to being

provided from a company's own on-premise servers. Cloud services are designed to provide easy, scalable access to applications, resources, and services and arefully managed by a cloud service provider. A cloud service can dynamicallyscale to meet the needs of its users, and because the service provider sup- plies the hardware and software necessary for the service, there is no need for a company to provision or deploy its own resources or allocate informa-tion technology (IT) staff to manage the service. Examples of cloud services include online data storage and backup solutions, web-based e-mail services,hosted office suites and document collaboration services, database process- ing, and managed technical support services.

Cloud services can be broadly classified into three types: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). With growing technologies, many more services are emerging in thisfield, such as Security as a Service (SeaaS), Knowledge as a Service, and DataAnalytics as a Service.

Many companies have come forward to adapt the cloud environment andensure that the users as well as the companies benefit from this. Amazon, Microsoft, Google, Yahoo, EMC, Salesforce, Oracle, IBM, and many more companies provide various tools and services in order to give cloud supportfor their customers.

11.1 EMC

EMC is one of the leading global enterprises that require dynamic scalability and infrastructure agility to meet changing applications as well as business needs. EMC chose cloud computing as the ideal solution to reduce the com- plexity and optimize the infrastructure. Offering Information Technology as a Service (ITaaS) reduces the energy consumption through resource sharing.

11.1.1 EMC IT

Virtualization is the main concept behind the success of EMC IT. By vir- tualizing the infrastructure, allocation of the resources on demand is possible. This also helps to increase efficiency and resource utilization.

EMC IT provides its business process units with IaaS, PaaS, and SaaS.Figure 11.1 gives an overview of the services offered by EMC, which are explained in the following:

1. IaaS offers EMC business units the ability to provision infrastruc- ture components such as network, storage, computing, and operat- ing systems individually or as integrated services.
2. PaaS provides the secure application and information frameworks on top of application server, web server, database, unstructured contentmanagement, and security components as a service to business unitsfrom which to develop solutions. EMC IT offers database platforms(Oracle Database as a Service, SQL Server as a Service, Greenplum as a Service) and application platforms (application development, Enterprise Content Management as a Service, Information Cycle Management as a Service, Security PaaS, Integration as a Service) forthe purpose of development.
3. SaaS provides applications and tools in a service model for businessenablement. EMC IT brought together several existing business solu- tions under the unified architecture named as Business Intelligence as a Service. It also offers Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) as a Service.

4. User Interface as a Service (UIaaS) provisions user and interface experience, rather than provisioning the actual device used.

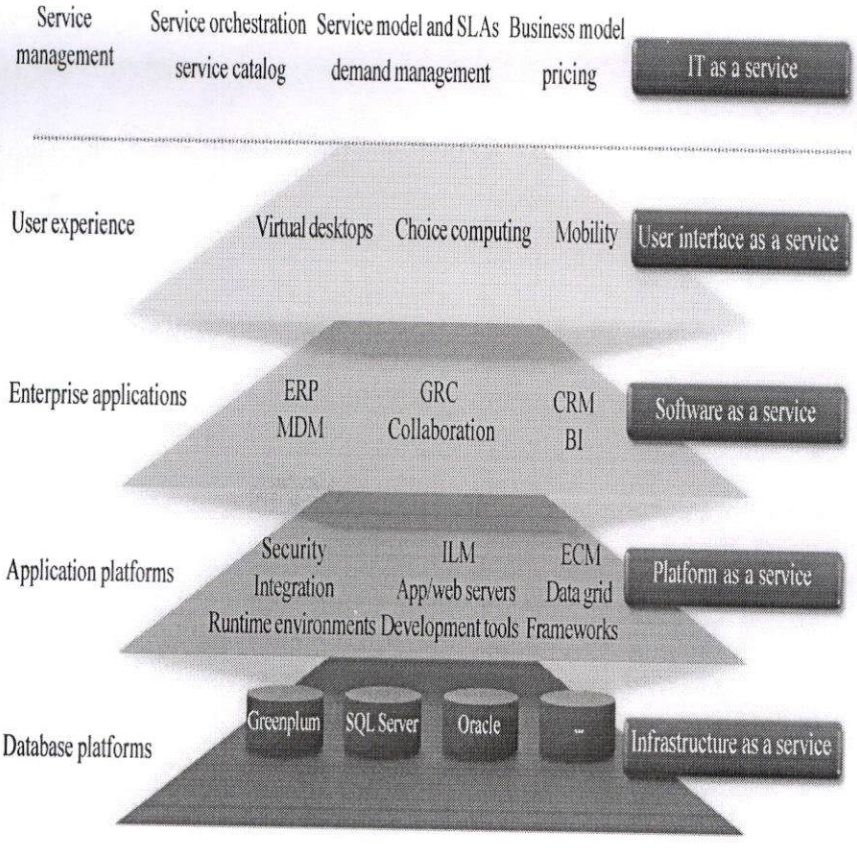


FIGURE 11.1
Cloud services by EMC. (Adapted from EMC IT's journey to the private cloud, applications andthe cloud

experience, White Paper-EMC.)

11.1.2 Captiva Cloud Toolkit

EMC offers a tool called *Captiva Cloud Toolkit* to help in the development of softwares. EMC Captiva Cloud Toolkit is a Software Development Kit (SDK)comprised of modules that help web application developers to quickly add scanning and imaging functionality directly to their web-based business applications. It is ideal for document capture vendors, commercial softwaredevelopers, and enterprises that want to create custom web-based appli- cations that are fully scan enabled, complimenting their business solution offerings.

Using Captiva Cloud Toolkit, developers can quickly create a working scan-enabled web-based business application in as early as 1 week. As a result, time to market is shortened and development, testing, and support costs are greatly reduced. Also, the enterprise's return on investment is quickly achieved, and its ability to compete in an increasingly competitive distributed document capture market is accelerated.

There are a few modules that are commonly used in most of the process development. These are basic modules that import images from various sources like fax, e-mail, or scanner or from any repository. A few of these modules are as follows:

1. **Scan**: Scanning is importing activity of documents into Captivafrom a scanner. Basically, scanning happens at page level to bring images page by page into Captiva. Scanning is the entry point to Captiva where one can import any kind of document like pdf, tiff, and jpg.
2. **MDW**: Multi Directory Watch is another entry point to Captiva. MDWcan be pointed to any folder/repository from where Captiva could import documents directly. MDW is very useful if business is gettingdocuments in the form of a soft copy, for example, as an attached filein an e-mail. MDW also acts as a scan module except it does not inter-lock with the scanner.
3. **IE**: Image enhancement is a kind of filter or repairing tool for imagesthat are not clear. It enhances the image quality, so it could be pro- cessed easily through Captiva. One can configure IE as per business requirement and images being received. The functionalities of IE aredeskew, noise removal, etc.
4. **Index:** Indexing is a data capturing activity in Captiva through which one can capture key data from various fields. For example,if bank form is being processed, the A/C no. and sort code could be the indexing field. Indexing could be added as per requirement of business. A validation field could be added to avoid unwanted dataentry while indexing any document.
1. **Export:** Export is the exit point of Captiva where images/data are sent to various repositories like file, net, document, or data. The exported dataare used for business requirements of various business divisions. Forexample, if we are capturing the A/C no. and sort code for a bank appli-cation, this could be mapped to any department where it is needed.
2. **Multi**: Multi is the last process in Captiva to delete batches that havegone through all modules and exported value successfully. Multi could be configured as per need of business. In the case when it is required to take a backup of batches, this module could be avoided.

The previously mentioned modules are very basic modules of Captiva for indexing and exporting. But for more flexibility and automation, dispatcher is used, which is more accurate to capture data.

11.2 Google

Google is one among the leading cloud providers that offer secure storage ofuser's data. It provides cloud platform, app engine, cloud print, cloud connect,and many more features that are scalable, reliable, as well as secure. Google offersmany of these services for free or at a minimum cost making it user friendly.

11.2.1 Cloud Platform

Google Cloud Platform enables developers to build, test, and deploy applica- tions on Google's highly scalable and reliable infrastructure. Google has oneof the largest and most advanced networks across the globe. Software infra- structures such as MapReduce, BigTable, and Dremel are the innovations forindustrial development.

Google Cloud Platform includes virtual machines, block storage, NoSQL datastore, and big data analytics. It provides a range of storage services thatallow easy maintenance and quick access of user's data. The cloud platformoffers a fully managed platform as well as flexible virtual machines allow- ing the user to choose as per the requirements. Google also provides easy integration of user's application within the cloud platform.

Applications hosted on the cloud platform can automatically scale up to handle the most demanding workloads and scale down when traffic sub- sides. The cloud platform is designed to scale like Google's own products, even when there is a huge traffic spike. Managed services such as App Engine or Cloud Datastore provide autoscaling that enables application to grow with the users. The user has to pay only for what he or she uses.

11.2.2 Cloud Storage

Google Cloud Storage is a RESTful online file storage web service for storingand accessing one's data on Google's infrastructure. Representational state transfer (REST) is an architectural style consisting of a coordinated set of architectural constraints applied to components, connectors, and data ele- ments within a distributed system. The service combines the performance and scalability of Google's cloud with advanced security and sharing capa- bilities. Google Cloud Storage is safe and secure. Data are protected through redundant storage at multiple physical locations.

The following are the few tools for Google Cloud Storage:

- *Google Developers Console* is a web application where one can per- form simple storage management tasks on the Google Cloud Storagesystem.
- *gsutil* is a Python application that lets the user access Google Cloud Storage from the command line.

11.2.3 Google Cloud Connect

Google Cloud Connect is a feature provided by Google Cloud by integratingcloud and the application programming interface (API) for Microsoft Office.After installing a plug-in for the Microsoft Office suite of programs, one cansave files to the cloud. The cloud copy of the file becomes the master docu- ment that everyone uses. Google Cloud Connect assigns each file a unique URL that can be shared to let others view the document.

If changes are made to the document, those changes will show up for everyone else viewing it. When multiple people make changes to the same section of a document, Cloud Connect gives chance to the user to choose which set of changes to keep.

When the user uploads a document to Google Cloud Connect, the service inserts some

metadata into the file. Metadata is information about other information. In this case, the metadata identifies the file so that changes will track across all copies. The back end is similar to the Google File System and relies on the Google Docs infrastructure. As the documents sync to the mas-ter file, Google Cloud Connect sends the updated data out to all downloadedcopies of the document using the metadata to guide updates to the right files.

11.2.4 Google Cloud Print

Google Cloud Print is a service that extends the printer's function to any device that can connect to the Internet. To use Google Cloud Print, the user needs to have a free Google profile, an app, a program, or a website that incorporates the Google Cloud Print feature, a cloud-ready printer or printerconnected to a computer logged on to the Internet.

When Google Cloud Print is used through an app or website, the print request goes through the Google servers. Google routes the request to the appropriate printer associated with the user's Google account. Assuming therespective printer is on and has an active Internet connection, paper, and ink,the print job should execute on the machine. The printer can be shared withother people for receiving documents through Google Cloud Print.

Because most printers are not cloud ready, most Google Cloud Print userswill need to have a computer act as a liaison. Google Cloud Print is an extension built into the Google Chrome Browser, but it should be enabled explicitly. Once enabled, the service activates a small piece of code calleda connector. The connector's job is to interface between the printer and the outside world. The connector uses the user's computer printer software to send commands to the printer.

If one has a cloud-ready printer, one can connect the printer to the Internet directly without the need for a dedicated computer. The cloud printer has tobe registered with Google Cloud Print to take advantage of its capabilities.

Because Google allows app and website developers to incorporate GoogleCloud Print into their products as they see fit, there is no standard approachto executing a print job. Google Cloud Print depends on developers incorpo-rating the feature into their products. Not every app or site will have GoogleCloud Print built into it, which limits its functionality. Naturally, Google builds the service into its own products, but many people rely on services from multiple sources and may find Google Cloud Print does not have a wide enough adoption to meet all their needs.

11.2.5 Google App Engine

Google App Engine lets the user run web applications on Google's infrastruc-ture. App Engine applications are easy to build, easy to maintain, and easy toscale as traffic and data storage needs grow. With App Engine, there are noservers to maintain: Just upload the application, and it is ready to serve users. The app can be served from the user's own domain name (such as http://www.example.com/) using Google Apps. Otherwise, it can be served using afree name on the appspot.com domain. An application can be shared with theworld or limit access to members of an organization. Figure 11.2 shows the dif-ferent modules in Google App Engine. Integration of cloud computing services with support services and client capabilities is shown in the diagram.

Google App Engine supports apps written in several programming lan- guages. With App Engine's Java runtime environment, one can build one's appusing standard Java technologies, including the JVM, the Java servlets, and the Java programming language—or any other language. App Engine also featuresa Python runtime environment, which includes a fast Python interpreter and thePython standard library. App Engine also features a PHP runtime, with nativesupport for Google Cloud SQL and Google Cloud Storage that works just likeusing a

local MySQL instance and doing local file writes. Finally, App Engine.

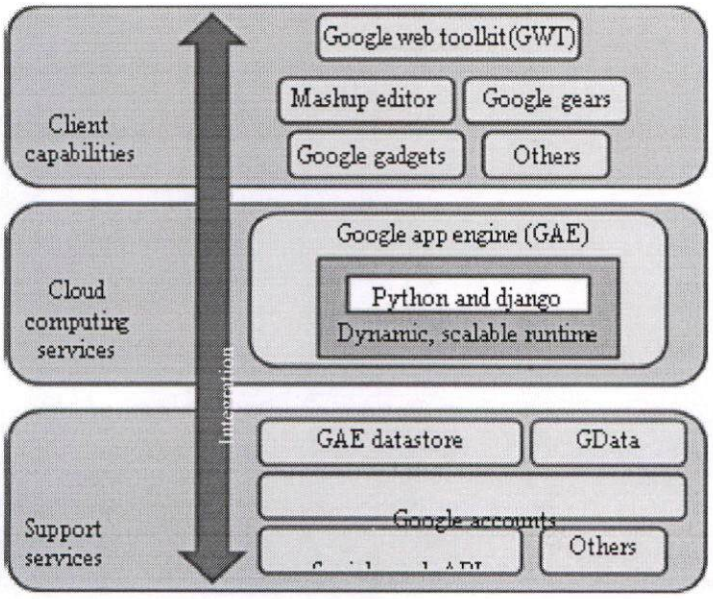


FIGURE 11.2
Google App Engine. (Adapted from http://rdn-consulting.com/blog/tag/azure/, accessed January 16, 2014).

provides a Go runtime environment that runs natively compiled Go code. These runtime environments are built to ensure that your application runs quickly,securely, and without interference from other apps on the system.

With App Engine also, the user has to only pay for what he or she uses. There are no setup costs and no recurring fees. The resources used by the application such as storage and bandwidth are measured in gigabyte and billed at competitive rates. One has to control the maximum amount of resources one's app can consume, so it always stays within one's budget.

App Engine costs nothing to get started. All applications can use up to1 GB of storage and enough CPU and bandwidth to support an efficient appserving around five million page views a month, absolutely free. When bill-ing is enabled for the application, free limits are raised, and one has to only pay for resources one uses above the free levels.

11.3 Amazon Web Services

Amazon Web Services (AWS) is a collection of remote computing services(also called web services) that together make up a cloud computing platform,offered over the Internet by Amazon.com. The most central and well knownof these services are Amazon Elastic Compute Cloud (Amazon EC2), AmazonSimple Queue Service (Amazon SQS), and Amazon S3 as shown in Figure 11.3.Amazon EC2 is a computing service, whereas Amazon SQS and Amazon S3 are support services. The service is advertised as providing a large

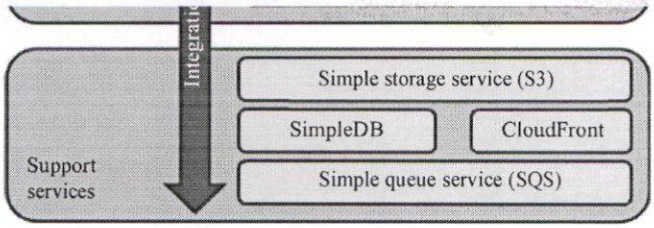


FIGURE 11.3
AWS. (Adapted from http://rdn-consulting.com/blog/tag/azure/, accessed January 16, 2014).

computing capacity (potentially many servers) much faster and cheaper than building a physical server farm. Amazon's data centers are locatedat Ashburn, Virginia, Dallas/Fort Worth, Los Angeles, Miami, Newark, New Jersey, Palo, Alto, California, Seattle, St. Louis, Amsterdam, Dublin, Frankfurt, London, Hong Kong, Singapore, Tokyo, etc.

11.3.1 Amazon Elastic Compute Cloud

Amazon EC2 is an IaaS offered by AWS and is the leading provider of IaaS in the current market. Powered by a huge infrastructure that the company has built to run its retail business, Amazon EC2 provides a true virtual com-puting environment. By providing a variety of virtual machine or instance types, operating systems, and software packages to choose from, Amazon EC2 enables the user to instantiate virtual machines of his choice through a web service interface. The user can change the capacity and characteristics ofthe virtual machine by using the web service interfaces, hence named *elastic*. Computing capacity is provided in the form of virtual machines or server instances by booting Amazon Machine Images (AMI), which can be instanti-ated by the user. An AMI contains all the necessary information needed to create an instance. The primary Graphical User Interface (GUI) interface is the AWS Management Console (point and click) and a web service API thatsupports both Simple Object Access Protocol and Query Requests. The API provides programming libraries and resources for Java, PHP, Python, Ruby,Windows, and .Net. The infrastructure is virtualized by using Xen hypervi- sor, and different instance types are provided as follows:

- Standard instances—suitable for most applications
- Micro instances—suitable for low-throughput applications
- High-memory instances—suitable for high-throughput applications
- High-CPU instances—suitable for compute-intensive applications
- Cluster compute instances—suitable for high-performance comput-ing (HPC) applications

The instances can be obtained on demand on an hourly basis, thus eliminat-ing the need of forecasting computing needs earlier. Instances can be reservedearlier, and a discounted rate is charged for such instances. Users can also bid on unused Amazon EC2 computing capacity and obtain instances. Suchinstances are called as Spot Instances. Those bids that exceed the current Spot Price is provided with the instance, which allows the user to reduce costs. The Spot Price is varying and is decided by the company.

Instances can be placed in multiple locations, which are defined by regionsand availability zones. Availability zones are distinct locations that are engi-neered to be insulated from failures in other availability zones and provide inexpensive, low-latency network connectivity to other availability zones inthe same region. Thus, placing the instances in multiple locations enables fault tolerance and failover reliability. The Amazon EC2 instances can be monitored and controlled by the AWS Management Console and the web service API. However, AWS provides Amazon Cloud Watch, a web service that provides monitoring for AWS cloud resources, starting with Amazon EC2. It provides customers with visibility into resource utilization, opera- tional performance, and overall demand patterns—

including metrics such as CPU utilization, disk reads and writes, and network traffic.

Instances are authenticated using a signature-based protocol, which uses key pairs. Another important feature provided is the Amazon Virtual PrivateCloud (Amazon VPC). The existing IT infrastructure can be connected to Amazon EC2 via a virtual private network (VPN). Isolated computing resources are provided in Amazon VPC, and the existing management capa- bilities such as security services, firewalls, and intrusion detection systems can be extended to isolated resources of Amazon EC2.

Elastic load balancing (ELB) enables the user to automatically distribute and balance the incoming application's traffic among the running instances based on metrics such as request count and request latency. Fault tolerance and automatic scaling can be performed by configuring the ELB as per the specific needs. ELB monitors the health of the instances running and routes traffic away from a failing instance.

An instance is stored as long as it is operational and is removed on termi- nation. Persistent storage can be enabled by using either Elastic Block Storage (EBS) or Amazon Simple Storage Service (S3). EBS provides a highly reliable and secure storage, and the storage volumes can be used to boot an Amazon EC2 instance or be attached to an instance as a standard block device. Amazon S3 provides a highly durable storage infrastructure designed for mission- critical and primary data storage. Storage is based on units called objects whose size can vary from one byte to five gigabytes of data. These objects are stored in a bucket and retrieved via a unique, developer-assigned key.

It is accessible through a web service interface and provides authentication procedures to protect against unauthorized access.

11.3.2 Amazon Simple Storage Service

Amazon Simple Storage Service known as Amazon S3, is the storage for the Internet. It is designed to make web-scale computing easier for developers. Amazon S3 provides a simple web service interface that can be used to store and retrieve any amount of data, at any time, from anywhere on the web. It gives any developer access to the same highly scalable, reliable, secure, fast, inexpensive infrastructure that Amazon uses to run its own global net- work of websites. The service aims to maximize benefits of scale and to pass those benefits on to developers.

Along with its simplicity, it also takes care of other features like security, scalability, reliability, performance, and cost. Thus, Amazon S3 is a highly scalable, reliable, inexpensive, fast, and also easy to use service that meets design requirements and expectations.

Amazon S3 provides a highly durable and available store for a variety of content, ranging from web applications to media files. It allows users to offload storage where one can take advantage of scalability and pay- as-you-go pricing. For sharing content that is either easily reproduced or where one needs to store an original copy elsewhere, Amazon S3's Reduced Redundancy Storage (RRS) feature provides a compelling solution. It also provides a better solution in the case of storage for data analytics. Amazon S3 is an ideal solution for storing pharmaceutical data for analysis, financial data for computation, and images for resizing. Later this content can be sent to Amazon EC2 for computation, resizing, or other large-scale analytics without incurring any data transfer charges for moving the data between the services.

Amazon S3 offers a scalable, secure, and highly durable solution for backup and archiving critical data. For data of significant size, the AWS Import/ Export feature can be used to move large amounts of data into and out of AWS with physical storage devices. This is ideal for moving large quantities of data for periodic backups, or quickly retrieving data for disaster recov- ery scenarios. Another feature offered by Amazon S3 is its Static Website

Hosting, which is ideal for websites with static content, including html files, images, videos, and client-side scripts such as JavaScript.

11.3.3 Amazon Simple Queue Service

Another service of AWS is Amazon SQS. It is a fast, reliable, scalable, fully managed message queuing service. SQS makes it simple and cost effective todecouple the components of a cloud application. SQS can be used to transmit any volume of data, at any level of throughput, without losing messages or requiring other services to be always available.

Amazon SQS is a distributed queue system that enables web service appli-cations to quickly and reliably queue messages that one component in the application generates to be consumed by another component. A queue is a temporary repository for messages that are waiting to be processed.

Amazon SQS offers various features like allowing multiple readers and writers at the same time, providing access control facilities, guaranteeing high availability of sending, and retrieving messages due to redundant infrastructure. It also gives provision for having variable length messages aswell as configurable settings for each queue.

11.1 Microsoft

Cloud computing provides a new way of looking at IT at Microsoft called Microsoft IT (MSIT). Cloud computing is now the preferred and default envi-ronment for new and migrated applications at Microsoft. MSIT has devel- oped a methodology and a set of the best practices for analyzing their currentapplication portfolio for possible candidates to migrate to cloud computing. This analysis enables MSIT to select the ideal cloud computing–based envi- ronment for each application. MSIT has captured these best practices and documented them for other Microsoft customers who wish to migrate their organizations to cloud computing.

11.1.1 Windows Azure

Windows Azure Cloud Services (web and worker roles/PaaS) allow develop-ers to easily deploy and manage application services. It delegates the man- agement of underlying role instances and operating system to the WindowsAzure platform.

The Migration Assessment Tool (MAT) for Windows Azure encapsulates all the information to be aware of before attempting the application migra- tion to Windows Azure. Based on the response to a series of simple binary questions, the tool generates a report that outlines the amount of develop- ment effort involved to migrate the application, or the architecture consider-ations for a new application.

The Windows Azure Pricing Calculator analyzes an application's poten- tial public cloud requirements against the cost of the application's existing infrastructure. This tool can help to compare current operational costs for anapplication, against what the operating costs would be on Windows Azure and SQL Azure.

Windows Azure Pack for Windows Server is a collection of Windows Azure technologies available to Microsoft customers at no additional cost for installation into their data center. It runs on top of Windows Server 2012.

R2 and System Center 2012 R2 and, through the use of the Windows Azure technologies, it allows you to offer a rich, self-service, multitenant cloud, con- sistent with the public Windows Azure experience.

11.1.2 Microsoft Assessment and Planning Toolkit

The Microsoft Assessment and Planning Toolkit (MAP) is an agentless, automated, multiproduct planning and assessment tool for cloud migration. MAP provides detailed readiness assessment reports, executive proposals, and hardware and software information. It also provides recommendations to help organizations accelerate the application migration process for both private and public cloud planning assessments. MAP analyzes server uti- lization data for server virtualization and also server consolidation with Hyper-V.

11.3.4 SharePoint

Microsoft offers its own online collaboration tool called SharePoint. Microsoft SharePoint is a web application platform that comprises a multi- purpose set of web technologies backed by a common technical infrastruc- ture. By default, SharePoint has a Microsoft Office–like interface, and it is closely integrated with the Office suite. The web tools are designed to be usable by nontechnical users. SharePoint can be used to provide intranet portals, document and file management, collaboration, social networks, extranets, websites, enterprise search, and business intelligence. It also has system integration, process integration, and workflow automation capabili- ties. Unlike Google Cloud Connect, Microsoft SharePoint is not a free tool. But it has additional features that cannot be matched by Google or anyother companies.

11.4 IBM

IBM is one among the players in the field of cloud computing offering vari- ous cloud services to the consumers. IBM cloud computing consists of cloudcomputing solutions for enterprises as offered by the global IT company IBM. All offerings are designed for business use, marketed under the name IBM SmartCloud. IBM cloud includes IaaS, SaaS, and PaaS offered through public, private, and hybrid cloud delivery models, in addition to the compo- nents that make up those clouds.

IBM offers an entry point to cloud computing whether a client is designingtheir own virtual private cloud, deploying cloud service, or consuming cloudworkload applications. The IBM cloud framework begins with the physical

hardware of the cloud. IBM offers three hardware platforms for cloud com- puting, which offer built-in support for virtualization. The next layer of the IBM framework is virtualization. IBM offers IBM Websphere application infrastructure solutions that support programming models and open stan- dards for virtualization.

The management layer of the IBM cloud framework includes IBM Tivoli mid- dleware. Management tools provide capabilities to regulate images with auto-mated provisioning and deprovisioning, monitor operations, and meter usage while tracking costs and allocating billing. The last layer of the framework pro-vides integrated workload tools. Workloads for cloud computing are servicesor instances of code that can be executed to meet specific business needs. IBM offers tools for cloud-based collaboration, development and test, application development, analytics, business-to-business integration, and security.

11.4.1 Cloud Models

IBM offers a spectrum of cloud delivery options ranging from solely privatecloud to solely

public cloud and numerous variations in between. IBM gives the option to build a customized cloud solution out of a combination of pub-lic cloud and private cloud elements. Companies that prefer to keep all dataand processes behind their own firewall can choose a private cloud solutionmanaged by their own IT staff. A company may also choose pay-as-you-go pricing that allows them to run lower-profile applications on a secure publiccloud model. Hybrid cloud options allow for some processes to be hosted and managed by IBM, while others are kept on a private cloud or on a VPNor Virtual Local Area Network. IBM also offers planning and consultation throughout the deployment process. Cloud computing is the best choice formobile software. IBM offers five different cloud provision models:

1. Private cloud, owned and operated by the customer
2. Private cloud, owned by the customer but operated by IBM (oranother provider)
3. Private cloud, owned and operated by IBM (or another provider)
4. Virtual private cloud services, based on multitenant support forindividual enterprises
5. Public cloud services, based on the provision of functions toindividuals

The majority of cloud users choose a hybrid cloud model, with some work- loads being served by internal systems, some from commercial cloud pro- viders, and some from public cloud service providers.

For enterprise customers who perceive that the security risk of cloud com-puting adoption is too high, IBM specializes in secure private cloud offerings.

For building strictly private clouds, IBM offers IBM Workload Deployer andCloudburst as ready-to-deploy, *cloud in a box*–style solutions. Cloudburst provides blade servers, middleware, and virtualization for an enterprise to build its own cloud-ready virtual machines. Workload Deployer connects an enterprise's existing servers to virtualization components and middleware in order to help deploy standardized virtual machines designed by IBM. Forcustomers who prefer to perform their own integration of private clouds, IBM offers a choice of hardware and software building blocks, along with recommendations and reference architecture, leading the way to deploy- ment. Clients may choose from IBM virtualization–enabled servers, middle-ware, and SaaS applications.

11.4.2 IBM SmartCloud

IBM SmartCloud is a branded ecosystem of cloud computing productsand solutions from IBM. It includes IaaS, SaaS, and PaaS offered through public, private, and hybrid cloud delivery models. IBM places these offeringsunder three umbrellas: SmartCloud Foundation, SmartCloud Services, and SmartCloud Solutions. Figure 11.4 briefly explains the architecture of IBM SmartCloud.

SmartCloud Foundation consists of the infrastructure, hardware, provisioning, management, integration, and security that serve as the underpinnings of a private or hybrid cloud. Built using those founda- tional components, PaaS, IaaS, and backup services make up SmartCloud Services. Running on this cloud platform and infrastructure, SmartCloud Solutions consist of a number of collaboration, analytics, and marketing SaaS applications.

Along with IaaS, PaaS, and SaaS, IBM also offers Business Process as a Service (BPaaS). Infrastructure cloud services provide the consumer the pro- vision of processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. In platform cloud services, a consumer can deploy consumer-created or consumer-acquired applications onto the cloud infrastructure created using programming lan- guages and tools

supported by the provider. Application cloud services allow consumers to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-basede-mail). Business process cloud services are any business process (horizon- tal or vertical) delivered through the cloud service model (multitenant, self-service provisioning, elastic scaling, and usage metering or pricing) via the Internet with access via web-centric interfaces and exploiting web-oriented cloud architecture. The BPaaS provider is responsible for the related busi- ness functions.

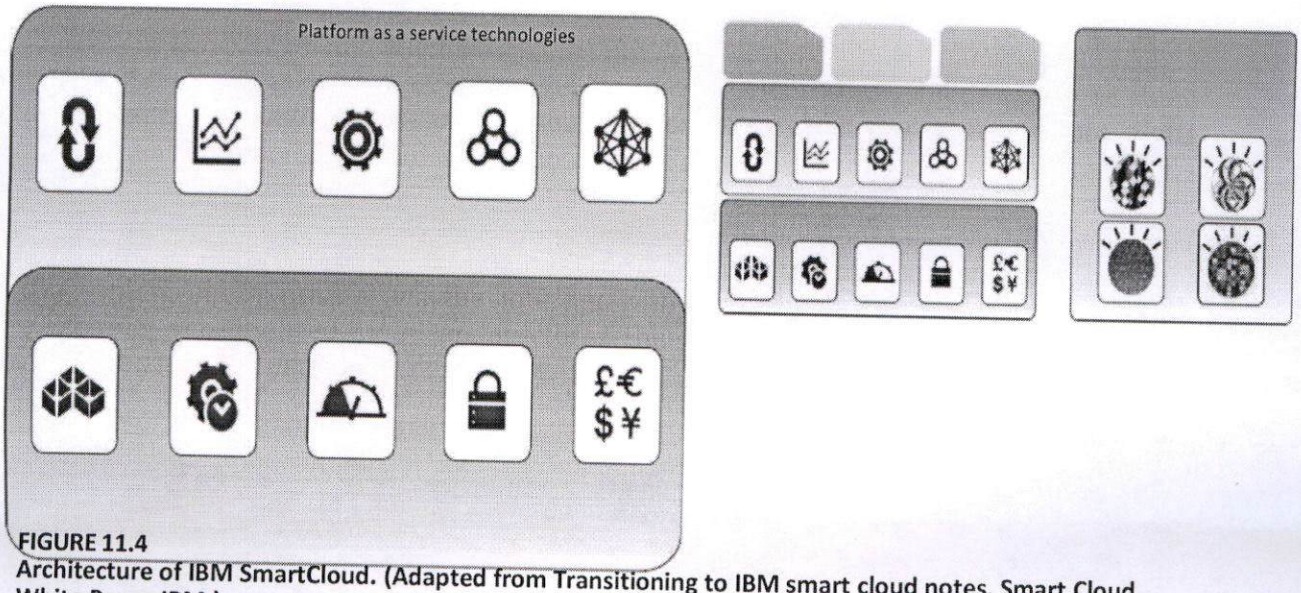


FIGURE 11.4
Architecture of IBM SmartCloud. (Adapted from Transitioning to IBM smart cloud notes, Smart Cloud White Paper-IBM.)

IBM SmartCloud foundation

11.5 SAP Labs

SAP Labs makes enterprise software to manage business operations and cus-tomer relations. SAP is the leader in the market of enterprise applications in terms of software and software-related service. The company's best-known software products are its enterprise resource planning application systems and management (SAP ERP), its enterprise data warehouse product—SAP Business Warehouse (SAP BW), SAP Business Objects software, and most recently, Sybase mobile products and in-memory computing appliance SAP HANA. SAP is one of the largest software companies in the world.

11.5.1 SAP HANA Cloud Platform

SAP HANA Cloud Platform is an open-standard, Eclipse-based, modular PaaS. In SAP

HANA Cloud Platform, applications are deployed via com- mand-line tools to the cloud as web application archive (WAR) files or OSGibundles. OSGi bundles are normal jar components with extra manifest head-ers. The applications run within the Java-based SAP HANA Cloud Platformruntime environment. It is powered by SAP HANA and can be maintained using web-based management tools.

The main features of SAP HANA Cloud Platform are as follows:

- Enterprise platform built for developers
- Native integration with SAP and non-SAP software
- In-memory persistence
- Secure data platform
- Lightweight, modular runtime container for applications

SAP HANA Cloud Platform lets the users quickly build and deploy business and consumer applications that deliver critical new functionality to meet emerging business needs. It also helps connect users with customers in more engaging experiences. It provides connectivity based on the cloud connec- tivity service. As a result, the platform streamlines the integration of new applications at the lowest possible total cost of ownership. Support for openprogramming standards provides a low barrier entry for developers. This makes them productive from the start in building enterprise applications that can integrate with any SAP or non-SAP solution. No new coding skills are required to work with SAP HANA.

11.5.2 Virtualization Services Provided by SAP

ERP virtualization increases a project's return on investment by maximiz- ing hardware utilization. The business benefits of virtualization of ERP

applications are shorter development cycles, reduction in IT costs, improved availability, and energy saving. A joint service from SAP and VMware helps in transition to a more open and flexible private cloud platform based on proven virtualization technology.

11.1 Salesforce

Salesforce.com is a cloud computing and social enterprise SaaS provider based in San Francisco. Of its cloud platforms and applications, the com- pany is best known for its Salesforce CRM product, which is composedof Sales Cloud, Service Cloud, Marketing Cloud, Force.com, Chatter, and Work.com. In addition to its products and platforms, Salesforce.com createdAppExchange, a custom application building and sharing platform. The company also has consulting, deployment, and training services.

11.1.1 Sales Cloud

Sales Cloud refers to the *sales* module in Salesforce.com. It includes Leads, Accounts, Contacts, Contracts, Opportunities, Products, Pricebooks, Quotes, and Campaigns (limits apply). It includes features such as web-to-lead to support online lead capture, with autoresponse rules. It is designed to be a start-to-end setup for the entire sales process. Sales Cloud manages contact information and integrates social media and

real-time customer collabora- tion through Chatter. The Sales Cloud gives a platform to connect with cus- tomers from complete, up-to-date account information to social insights, all in one place and available anytime, anywhere. Everything is automatically pushed in real time, from contact information to deal updates and discount approvals.

Salesforce.com created the Sales Cloud to be as easy to use as a consumer website like Amazon and built it in the cloud to eliminate the risk and expense associated with traditional software. With its open architectureand automatic updates, the Sales Cloud does away with the hidden costs anddrawn-out implementations of traditional CRM software. By continuing to innovate and embrace technologies like mobile, collaboration, and social intelligence, the Sales Cloud has continued to pull ahead of the competition.

11.1.2 Service Cloud: Knowledge as a Service

Service Cloud refers to the *service* (as in *customer service*) module in Salesforce.com. It includes Accounts, Contacts, Cases, and Solutions. It also encom- passes features such as the public knowledge base, web-to-case, call center, and self-service portal, as well as customer service automation. Service Cloud

includes a call center–like case tracking feature and a social networking plug-in for conversation and analytics.

The Service Cloud delivers the world's first enterprise-grade knowledge base to run entirely on an advanced, multitenant cloud platform. That meansone can get all the cloud computing benefits that Salesforce.com is known for delivering without expensive data centers or software. Just powerful knowl-edge management, without the hassle of on-premises software, is provided.Unlike stand-alone applications, this knowledge base is fully integrated witheverything else. Service Cloud has to offer all the tools one needs to run the entire service operation. When the consumer's knowledge base is a core partof CRM solution, knowledge as a process can be managed. One can con- tinually create, review, deliver, analyze, and improve the knowledge. And, because it is delivered by the Service Cloud, user's knowledge is available wherever other customers need it. Agents have the right answers at their fin-gertips to communicate over the phone, send out through an e-mail, or sharevia a chat client. The same knowledge base serves up answers to the servicewebsite is a part of company's public site. If one wants to take advantage of social channels like Twitter or Facebook, one can easily share knowledge thatis tapped into the wisdom of the crowd to capture new ideas or answers. Allthis is done securely.

The Service Cloud gives the tools that are needed to manage knowledge at enterprise scale. But it also delivers the same great ease of use that Salesforce.com is known for. That means user will benefit no matter what size or how complex the business is.

11.1 Rackspace

Rackspace Cloud, a part of Rackspace, is another player in the cloud comput-ing market. Offering IaaS to clients, it has been used by a large number ofenterprises. Rackspace Cloud offers three cloud computing solutions—CloudServers, Cloud Files, and Cloud Sites. Cloud Servers provide computationalpower on demand in minutes; Cloud Sites are for robust and scalable webhosting, and Cloud Files are for elastic online file storage and content delivery.Cloud Servers is an implementation of

IaaS where the computing capac- ity is provided as virtual machines that run in the Cloud Servers systems.The virtual machine instances are configured with different amounts ofcapacities. The instances come in different flavors and images. A flavor is anavailable hardware configuration for a server. Each flavor has a unique com-bination of disk space, memory capacity, and priority for CPU time. A varied set of instances are available for the user to choose from.

These virtual machines are instantiated using images. An image is a collec-tion of files used to create or rebuild a server. A variety of prebuilt operating system images are provided by Rackspace Cloud (64-bit Linux distributions—Ubuntu, Debian, Gentoo, CentOS, Fedora, Arch, and Red Hat Enterprise Linux)or Windows Images (Windows Server 2008 and Windows Server 2003). Theseimages can be customized to the user's choice to create custom images.

The Cloud Servers systems are virtualized using the Xen Hypervisor for Linux and Xen Server for Windows. The virtual machines that are generatedcome in different sizes and measured based on the amount of physical memoryreserved. Currently, the physical memory can vary from 256 MB to 15.5 GB. Inthe event of availability of extra CPU power, Rackspace Cloud claims to pro-vide extra processing power to the running workloads, free of cost.

Backup schedules can be created to define when to create server images.This is a useful feature, which enables the user to continue work in the eventof failures by using the backup images. Custom images are helpful in creatingbackup schedules. A type of images, referred to as *gold* server images, can beproduced if the servers of that configuration are to be instantiated frequently. Cloud Servers can be run through the Rackspace Cloud Control Panel (GUI) or programmatically via the Cloud Server API using a RESTful interface. Thecontrol panel provides billing and reporting functions and provides access tosupport materials including developer resources, a knowledge base, forums,and live chat. The Cloud Servers API was open sourced under the CreativeCommons Attribution 3.0 license. Language bindings via high-level languageslike C++, Java, Python, or Ruby that adhere to the Rackspace specification will beconsidered as Rackspace-approved bindings. The virtual machine instances are authenticated in the API by a token-based protocol that uses the HTTP x-Header. Private/public keys are used to ensure Secured Shell Access.

Cloud Servers scale automatically to balance load. This process is auto-mated and initiated from either the Rackspace Cloud Control Panel orthe Cloud Server API. The amount to scale is specified; the Cloud Serveris momentarily taken offline; the RAM, disk space, and CPU allotment areadjusted; and the server is restarted. A Cloud Server can be made to act as aload balancer using simple readily available packages from any of the distri-bution repositories. Rackspace Cloud is working on beta version of the CloudLoad Balancing product, which provides a complete load balancing solution.Cloud Servers are provided persistent storage through RAID10 disk stor-
age; thus, data persistency is enabled leading to better functioning.

11.1 VMware

VMware, a leader in virtualization technology, has come up with enterprise cloud computing solutions. Having been a dominating player in the virtual-ization domain, VMware is currently providing a range of products for the development of private and public clouds and for leveraging the services offered by both as a hybrid cloud, such as VMware vCloud Director, VMware vCloud Datacenter Services, VMware vSphere, and VMware vShield to namea few.

Private clouds enable the better usage and management of internal IT infra-structure than the traditional methods. Greater operational efficiency, secure, fault-tolerant, well-managed computing environments can be modeled and operated. VMware's private cloud offering provides greater standardiza- tion, rapid provisioning, and self-service for all applications and unparal- leled cost savings by consolidating their physical infrastructures. VMware's modular technology enables the user to select from a variety of hardware, software, and certified service providers to result in efficient cloud comput- ing. Thus, the family of products offered by VMware promotes compatibility and retains the choice of freedom for the users to obtain desired services.

Private clouds can be created by using the VMware vSphere and VMware vCloud Director. VMware vSphere is a robust virtualization platform used to transform IT infrastructures into virtual storage, compute, and network resources and provide them as a service within the organization. VMware vSphere provides services at both the infrastructure and application levels. At the infrastructure level, it provides options to perform efficient opera- tion and management of the compute, storage, and network resources.At the application level, service-level controls are provided for the applica- tions running on the underlying infrastructures, leading to available, secure,and scalable applications.

The VMware vCloud Director, coupled with VMware vSphere, is a soft- ware solution that enables enterprises to build secure, multitenant private clouds by pooling infrastructure resources into virtual datacenters and exposing them to users through web-based portals and programmatic inter- faces as fully automated, catalog-based services. VMware vCloud Director abstracts the virtual computing environment from the underlying resources and provides a multitenant architecture that features isolated virtual resources, independent LDAP authentication, specific policy controls, and unique catalogs. VMware vShield technologies are used to provide security to these environments by using services like perimeter protection, port-levelfirewall, NAT and DHCP services, site-to-site VPN, network isolation, and web load balancing. The VMware vCloud Director allows users to catalog infrastructure and application services of the desired configurations and deploy and consume them as needed. Interactions with the virtual data cen-ters or the catalogs are through a user-friendly web portal or the vCloud API.The vCloud API is an open, REST-based API that provides scripted access, complying with the open virtualization format (OVF). The API can be used along with VMware vCenter Orchestrator to automate and orchestrate oper-ational processes like routine tasks, activities, and workflows.

Public and hybrid cloud solutions are provided by VMware by partner- ing with other companies, certified as service providers. VMware vCloud Datacenter Services and VMware vCloud Express offer efficient solutions for utilizing IaaS either as a public cloud or a hybrid cloud. vCloud Datacenter Services provides a scalable environment, where internal resources are aug-mented with the external resources. vCloud Datacenter Services are builton the same technology and foundations as VMware vCloud Director and VMware vSphere to enable interoperability between cloud environments. Thus, the user is free to burst his private cloud into public cloud of his pre- ferred service provider.

vCloud Express is an IaaS offering delivered by leading VMware service provider partners. It is a cobranded service that provides reliable, on-demand, pay-as-you-go infrastructure. The VMware vCloud Express providers are Virtacore vCloud Express, Hosting.com, Melbourne IT, and Terremark's vCloud Express. Instance types, load balancing, storage options, and pricingvary between service providers.

11.1 Manjrasoft

Manjrasoft is one of the nonmajor providers of cloud services. But it has comeup with a platform called *Aneka* that provides a set of services that help the development of applications in an easier way. Manjrasoft develops market- oriented cloud computing platforms that allow one to build, accelerate, andmanage the applications ultimately saving one's time and money, leading toenhanced business productivity and profit.

11.1.1 Aneka Platform

Aneka provides a set of services that make enterprise cloud construction and development of applications as easy as possible without sacrificing flexibil- ity, scalability, reliability, and extensibility.

Figure 11.5 gives an overview of the Aneka platform. The key features sup-ported by *Aneka* are as follows:

1. A configurable and flexible execution platform (container) enabling plug- gable services and security implementations. Multiple authentication/authorization mechanisms such as role-based security and Windows domain–based authentication are considered for this purpose.
2. Multiple persistence options including Relational Database Manage- ment System (RDBMS), Structured Query Language (SQL) Express,MySQL, and flat files.
3. Software development kit (SDK) supporting multiple programming models including object-oriented thread model, task model for legacyapplications, and MapReduce model for data-intensive applications.
4. Custom tools such as Design Explorer for parameter sweep studies.

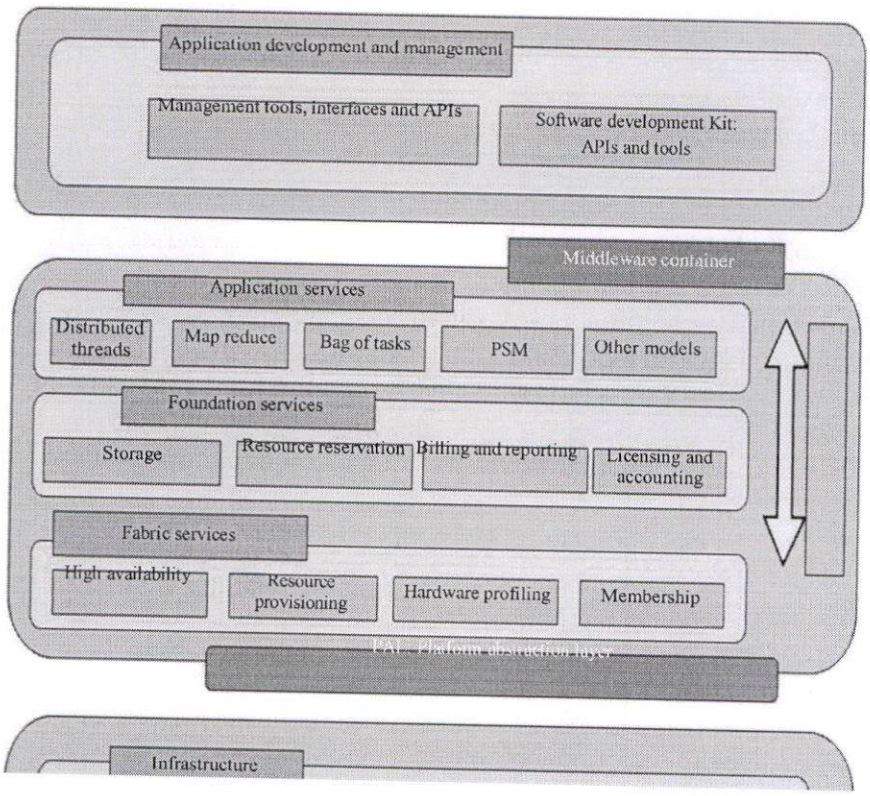


FIGURE 11.5
Overview of the Aneka platform. (Adapted from http://www.manjrasoft.com/aneka_architecture.html, accessed January 8, 2013.)

1. Easy to use management tool for SLA and Quality of Service (QoS) negotiation and dynamic resource allocation.
2. Supports deployment of applications on private or public clouds inaddition to their seamless integration.

Aneka allows servers and desktop PCs to be linked together to form a very powerful computing infrastructure. This allows companies to become energy efficient and save money without investing in a number of computersto run their complex applications.

Each *Aneka* node consists of a configurable container that includes infor- mation and indexing, scheduling, execution, and storage services. *Aneka* supports multiple programming models, security, persistence, and commu-nications protocols.

11.6 Summary

In this chapter, we have discussed about various companies that support cloud computing by providing tools and technologies to adapt to the cloud environment. Each section briefly describes the cloud features supported in these companies. Few of the services like Google Docs and Google Cloud Print are free, whereas that of AWS, Microsoft, etc., are proprietary. Based on the specific requirements, the user has to make a trade-off between open source and closed source tools/services. An attempt has been made to list the tools/services offered by each company in Table 11.1.

Though there are a number of companies, we have chosen few compa- nies that have progressed a lot in this area. Table 11.2 gives the information about few providers and the prices on a per hour basis along with the service

TABLE 11.1
Tools and Services Offered by Companies

Company Name	Tools/Services
EMC	Captiva Cloud toolkit
Google	Google App Engine, Google Docs, Google Cloud Connect Google Cloud Print
Amazon	Amazon EC2, Amazon S3, Amazon SQS

Microsoft	Microsoft Assessment and Planning Toolkit, Windows Azure Sharepoint
IBM	IBM Smart Cloud
Salesforce	Sales Cloud, Service Cloud
SAP LABS	SAP HANA Cloud
Vmware	vCloud
Manjrasoft	Aneka Platform
Red Hat	OpenShift Enterprise, OpenShift Origin
Gigaspaces	Cloudify

TABLE 11.2

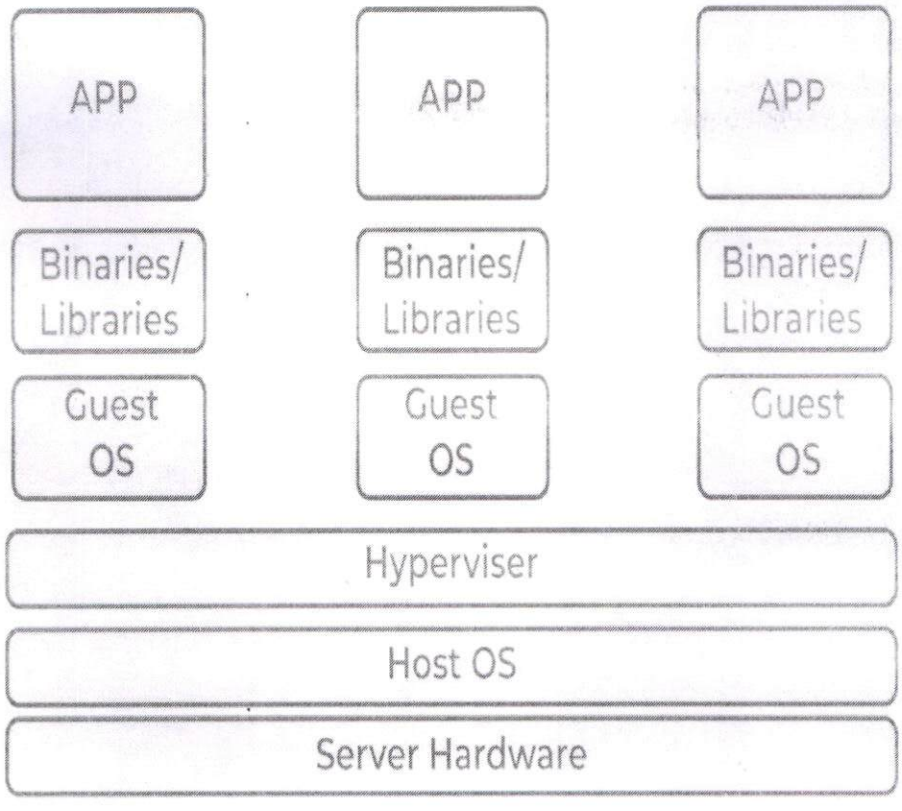
Details of Cloud Service Providers

Provider Name	Service Model	Deployment Model	Server Operating System
Amazon Web Services	IaaS	Public	Widows, Linux
Google App Engine	PaaS	Public	Windows
Windows Azure	IaaS	Public	Widows, Linux
IBM Cloud	IaaS	Private, hybrid	Widows, Linux
Salesforce Platform	PaaS	Public	Widows, Linux
Rackspace	IaaS	Public, private, hybrid	Widows, Linux
SAP HANA Cloud	PaaS	Public	Linux

model and deployment model offered by that system. Further details regard-ing the companies can be seen in the references section.

Virtualization

- It is a technique how to separate a service from the underlying physical delivery of that service.
- It is the process of creating a virtual version of something like computer hardware.
- It was initially developed during the mainframe era.
- It involves using specialized software to create a virtual or software-created version of a computing resource rather than the actual version of the same resource.
- With the help of Virtualization, multiple operating systems and applications can run on the same machine and its same hardware at the same time, increasing the utilization and flexibility of hardware.
- In other words, one of the main cost-effective, hardware-reducing, and energy-saving techniques used by cloud providers is Virtualization. Virtualization allows sharing of a single physical instance of a resource or an application among multiple customers and organizations at one time.
- It does this by assigning a logical name to physical storage and providing a pointer to that physical resource on demand. The term virtualization is often synonymous with hardware virtualization, which plays a fundamental role in efficiently delivering Infrastructure-as-a-Service (IaaS) solutions for cloud computing.
- Moreover, virtualization technologies provide a virtual environment for not only executing applications but also for storage, memory, and networking.



Virtualization

- Host Machine: The machine on which the virtual machine is going to be built is known as Host Machine.
- Guest Machine: The virtual machine is referred to as a Guest Machine.

Work of Virtualization in Cloud Computing

Virtualization has a prominent impact on Cloud Computing. In the case of cloud computing, users store data in the cloud, but with the help of Virtualization, users have the extra benefit of sharing the infrastructure. Cloud Vendors take care of the required physical resources, but these cloud providers charge a huge amount for these services which impacts every user or organization. Virtualization helps Users or Organisations in maintaining those services which are required by a company through external (third-party) people, which helps in reducing costs to the company. This is the way through which Virtualization works in Cloud Computing.

Benefits of Virtualization

- More flexible and efficient allocation of resources.
- Enhance development productivity.
- It lowers the cost of IT infrastructure.
- Remote access and rapid scalability.
- High availability and disaster recovery.
- Pay peruse of the IT infrastructure on demand.
- Enables running multiple operating systems.

Drawback of Virtualization

- **High Initial Investment:** Clouds have a very high initial investment, but it is also true that it will help in reducing the cost of companies.
- **Learning New Infrastructure:** As the companies shifted from Servers to Cloud, it requires highly skilled staff who have skills to work with the cloud easily, and for this, you have to hire new staff or provide training to current staff.
- **Risk of Data:** Hosting data on third-party resources can lead to putting the data at risk, it has the chance of getting attacked by any hacker or cracker very easily.

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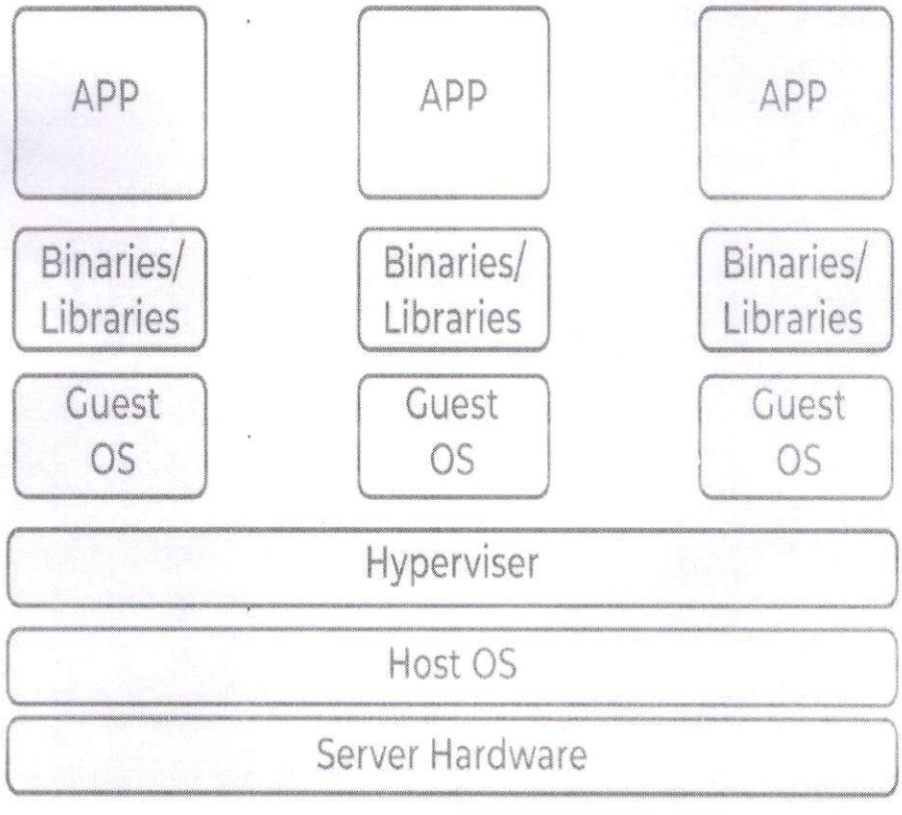

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Oracle cloud

Oracle cloud platform is offered by the **Oracle Corporation**. It combines Platform as a Service, Infrastructure as a Service, Software as a Service, and Data as a Service with cloud infrastructure. It is used to perform tasks such as moving applications to the cloud, managing development environment in the cloud, and optimize connection performance.

Features of Oracle cloud

- Oracle cloud provides various tools for build, integrate, monitor, and secure the applications.
- Its infrastructure uses various languages including, Java, Ruby, PHP, Node.js.
- It integrates with Docker, VMware, and other DevOps tools.
- Oracle database not only provides unparalleled integration between IaaS, PaaS, and SaaS, but also integrates with the on-premises platform to improve operational efficiency.
- It maximizes the value of IT investments.
- It offers customizable Virtual Cloud Networks, firewalls, and IP addresses to securely support private networks.

CMR College of Engineering & Technology

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B.TECH-IV/IV I SEM Regular Results Analysis Held in November 2023: Final Result Curriculum: R18 Rev2

Branch **ELECTRONICS & COMMUNICATION ENGINEERING**

Subject	Reg	App	Passed	Failed	Reg Pass %	Apprd. Pass %
NTREPRENEURSHIP :30164)	7	7	6	1	85.71	85.71
R POLLUTION & CONTROL \30163)	74	74	72	2	97.30	97.30
NVIRONMENTAL PROTECTION AND MANAGEMENT \30166)	39	39	39	0	100.00	100.00
/ASTE TO ENERGY \30378)	6	6	6	0	100.00	100.00
LOUD COMPUTING \30542)	17	17	15	2	88.24	88.24
NTRODUCTION TO DATA SCIENCE \30559)	10	10	9	1	90.00	90.00
A OF INSURANCE AND TAXATION C30165)	15	15	13	2	86.67	86.67
MARKETING MANAGEMNET C30167)	41	41	40	1	97.56	97.56
MAJOR PROJECT PHASE-I A30428)	249	249	225	24	90.36	90.36
MINI PROJECT-II A30426)	116	116	116	0	100.00	100.00
SUMMER INTERNSHIP-II (A30427)	133	133	133	0	100.00	100.00
ALL SUBJECTS	249	248	212	36	85.14	85.48

Branch **COMPUTER SCIENCE & ENGINEERING**

Subject	Reg	App	Passed	Failed	Reg Pass %	Apprd. Pass %
BUSINESS MANAGEMENT & FINANCIAL ANALYSIS (A30013)	260	258	247	11	95.00	95.74
D J PATTERNS 34)	226	225	214	11	94.69	95.11
MACHINE LEARNING (A30535)	34	34	31	3	91.18	91.18
DATA ANALYTICS WITH R (A30537)	59	59	55	4	93.22	93.22
DEEP LEARNING (A30538)	66	66	61	5	92.42	92.42
ETHICAL HACKING (A30539)	135	134	124	10	91.85	92.54
BIG DATA ANALYTICS (A30540)	172	171	167	4	97.09	97.66
CLOUD COMPUTING (A30542)	88	86	76	10	86.36	88.37
KNOWLEDGE MANAGEMENT (C30162)	50	49	45	4	90.00	91.84
PYTHON PROGRAMMING (A30531)	48	48	45	3	93.75	93.75

Controller of Examinations

Principal

Hall Ticket No. | | | | | | | | | | |

Question Paper Code: A30542

CMR COLLEGE OF ENGINEERING & TECHNOLOGY
(UGC AUTONOMOUS)

B.Tech VII Semester Regular Examinations June/July-2022
(Regulation: CMRCET-R18)

Subject Name: Cloud Computing

Computer Science and Engineering

Date: **Time: 3 hours** **Max.Marks:70**

PART-A

Answer all TEN questions (Compulsory)
Each question carries TWO marks. **10x2=20M**

1.	What do you mean by High Performance Computing?	2 M	L1
2.	Define Parallel Computing.	2 M	L1
3.	List down the properties of cloud computing.	2 M	L1
4.	What are the deployment models of the cloud?	2 M	L1
5.	What is public cloud access networking?	2 M	L1
6.	What are the drawbacks of a web application?	2 M	L1
7.	Define Infrastructure as a Service (IaaS).	2 M	L1
8.	List the responsibilities of cloud service providers.	2 M	L1
9.	List the tools/services provided by Microsoft	2 M	L1
10.	What is Google Cloud Print?	2 M	L1

PART-B

Answer any FIVE questions. One question from each unit either A or B (Compulsory)
Each question carries TEN Marks. **5x10=50M**

11. A.	Will mobile computing play a dominant role in the future? Analyze.	10M	L4
	OR		
11. B.	Compare and contrast Grid Computing and Cloud Computing.	10M	L2
12. A.	Explain a real-life example to illustrate the concepts behind cloud computing.	10M	L2
	OR		
12. B.	Illustrate the concept of private cloud with an example.	10M	L2
13. A.	Analyze how cloud anatomy is different from cloud architecture?	10M	L4
	OR		
13. B.	List and explain the phases of cloud migration.	10M	L2
14. A.	Examine the Platform as a service concept with a diagram.	10M	L4
	OR		
14. B.	Identify the two SaaS service provider in industry and examine the unique advantage of that industry.	10M	L3

15. A.	Explain the Amazon Elastic Compute Cloud (EC2)?	10M	L2
	OR		
15. B.	Explain the following: (3M+3M+4M) i) Google App Engine ii) Google Web Tool Kit iii) Microsoft Azure Services Platform	10M	L2

Hall Ticket No. | | | | | | | | | | | Question Paper Code:

CMR COLLEGE OF ENGINEERING & TECHNOLOGY
(UGC AUTONOMOUS)

B.Tech VII Semester Regular Examinations JANUARY-2022
(Regulation: CMRCET-R18)

Subject Name: Cloud Computing
(Department): CSE
Date: **Time: 3 hours** **Max.Marks:70**

PART-A
Answer all TEN questions (Compulsory)
Each question carries TWO marks. **10x2=20M**

1.	Compare parallel and distributed computing?	2 M	L2
2.	List out the Mobile Computing Applications?	2 M	L1
3.	What is the need of cloud computing?	2 M	L1
4.	What is Hybrid Cloud?	2 M	L1
5.	Define storage virtualization?	2 M	L3
6.	What are the benefits of cloud migration?	2 M	L1
7.	What are the characteristics of IaaS?	2 M	L1
8.	Demonstrate the applications of PaaS?	2 M	L2
9.	List out the various Cloud Service Providers?	2 M	L1
10.	What are the benefits of VMware?	2 M	L1

PART-B
Answer any FIVE questions. One question from each unit either A or B (Compulsory)
Each question carries TEN Marks. **5x10=50M**

11. A.	Discuss about classification of Distributed and Parallel Computing Systems?	10M	L6
	OR		
11. B.	Explain different computing paradigms in detail?	10M	L2
12. A.	Define cloud computing and explain principles of cloud computing?	10M	L5
	OR		
12. B.	Explain in detail about different service providers of Platform as a Service (PaaS) and its benefits?	10M	L5
13. A.	Define cloud computing and explain cloud architecture in detail with neat diagram?	10M	L5
	OR		
13. B.	Explain the network connectivity in cloud computing and its applications?	10M	L2
14. A.	What is IaaS and explain its advantages and disadvantages in detail?	10M	L2
	OR		
14. B.	Explain the pros and cons of PaaS and Software as a Service?	10M	L5

15. A.	Explain about Amazon Elastic cloud computing services in detail?	10M	L5
	OR		
15. B.	Explain IBM Smart Cloud architecture and its services in detail?	10M	L5

(You are requested to give division of marks in the marks column, If any sub questions are given in any question.)

NOTE:

1. Please see that the questions are within the scope of the syllabus, which can be written by Students in allotted 3 hours time.

Hall Ticket No. | | | | | | | | | | | Question Paper Code: A30542

CMR COLLEGE OF ENGINEERING & TECHNOLOGY
(UGC AUTONOMOUS)

B.Tech VII Semester Regular/Supplementary Examinations November-2023
(Regulation: CMRCET-R18)

Subject Name: CLOUD COMPUTING
(CSE)

Date: **Time: 3 hours** **Max.Marks:70**

PART-A
Answer all TEN questions (Compulsory)
Each question carries TWO marks. **10x2=20M**

1.	Differentiate Grid computing with Cloud computing.	2 M	L2
2.	Define Cloud Computing and mention any three cloud services examples	2 M	L1
3.	List out benefits of Cloud Component Model approach	2 M	L3
4.	Mention the challenges of cloud computing.	2 M	L3
5.	List out are the various layers of SOA?	2 M	L1
6.	Name the steps involved in providing VM.	2 M	L3
7.	Mention the various public cloud offerings of PaaS.	2 M	L3
8.	Discuss the various Pros of SaaS	2 M	L2
9.	What are the basic modules of EMC's Captiva Cloud Toolkit?	2 M	L1
10.	Write a brief note on Google's Cloud storage.	2 M	L2

PART-B
Answer any FIVE questions. One question from each unit either A or B (Compulsory)
Each question carries TEN Marks. **5x10=50M**

11. A.	Explain about cloud computing model and its benefits	10M	L2
	OR		
11. B.	How cloud computing is different from traditional on premise computing? How properties like elasticity and scalability influence cloud computing?	10M	L3
12. A.	Describe possible services that can be achieved through IaaS Cloud deployment models	10M	L3
	OR		
12. B.	Discuss the capabilities that the cloud users can get through Platform as a serice (PaaS). Also mention key characteristics of PaaS.	10M	L6
13. A.	Explain the role of Network Connectivity in Cloud Computing and explain how to attain QoS by managing by managing cloud.	10M	L2
	OR		
13. B.	Draw and explain the iterative seven step model of migration into the cloud.	10M	L3
14. A.	Summarize the cloud service model of the following: 1. Need of SaaS 2. Pros and cons of SaaS 3. Suitability of SaaS 4. About SaaS providers	10M	L2
	OR		
14. B.	When we need various cloud services how we can get advantages of cloud services by a newly established companies. Explain in detail.	10M	L1

15. A.	Demonstrate out and brief the features of Amazon Simple Queue Service and cloud services provided by Windows Azure.	10M	L2
	OR		
15. B.	Discuss about Amazon sample storage service and simple queue google cloud connect.	10M	L3

(You are requested to give division of marks in the marks column, If any sub questions are given in any question.)

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CMR COLLEGE OF ENGINEERING & TECHNOLOGY
(UGC AUTONOMOUS)

B.Tech VII Semester Regular Examinations November-2023

(Regulation: CMRCET-R18)

Subject Name: Cloud Computing

CSE

Date: **Time: 3 hours** **Max.Marks:70**

PART-A

Answer all TEN questions (Compulsory)

Each question carries TWO marks. **10x2=20M**

1.	Define Bio Computing.	2 M	L1
2.	What is Parallel Computing?	2 M	L1
3.	What is the need for Cloud Computing?	2 M	L1
4.	Describe the motivation for Cloud Computing.	2 M	L6
5.	Explain anatomy of the cloud.	2 M	L5
6.	List out the phases of cloud migration approaches.	2 M	L4
7.	What is the suitability of IaaS?	2 M	L1
8.	Illustrate the summary of SaaS providers.	2 M	L2
9.	Define Google Cloud Print.	2 M	L1
10.	Define Amazon Simple Queue.	2 M	L1

PART-B

Answer any FIVE questions. One question from each unit either A or B (Compulsory)

Each question carries TEN Marks. **5x10=50M**

11. A.	Write a short note on the following i) High-Performance Computing ii) Nano Computing iii) Distributed Computing iv) Grid Computing v) Cloud Computing	10M	L2
	OR		
11. B.	Compare and contrast Mobile Computing and Quantum Computing.	10M	L2
12. A.	Describe Cloud Computing Is a Service in detail.	10M	L6
	OR		
12. B.	Discuss Cloud Computing Is a Platform in detail.	10M	L6
13. A.	How to manage a cloud application? Discuss.	10M	L6
	OR		
13. B.	Explain the cloud architecture with a neat sketch.	10M	L5

14. A.	**What are cloud service models other than IaaS, PaaS and SaaS?**	10M	L1
	OR		
14. B.	**Explain the characteristics of IaaS and write its pros and cons.**	10M	L5
15. A.	**Discuss Amazon Elastic Compute Cloud in detail.**	10M	L6
	OR		
15. B.	**Describe Google App Engine.**	10M	L6

(You are requested to give division of marks in the marks column, If any sub questions are given in any question.)

NOTE:

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